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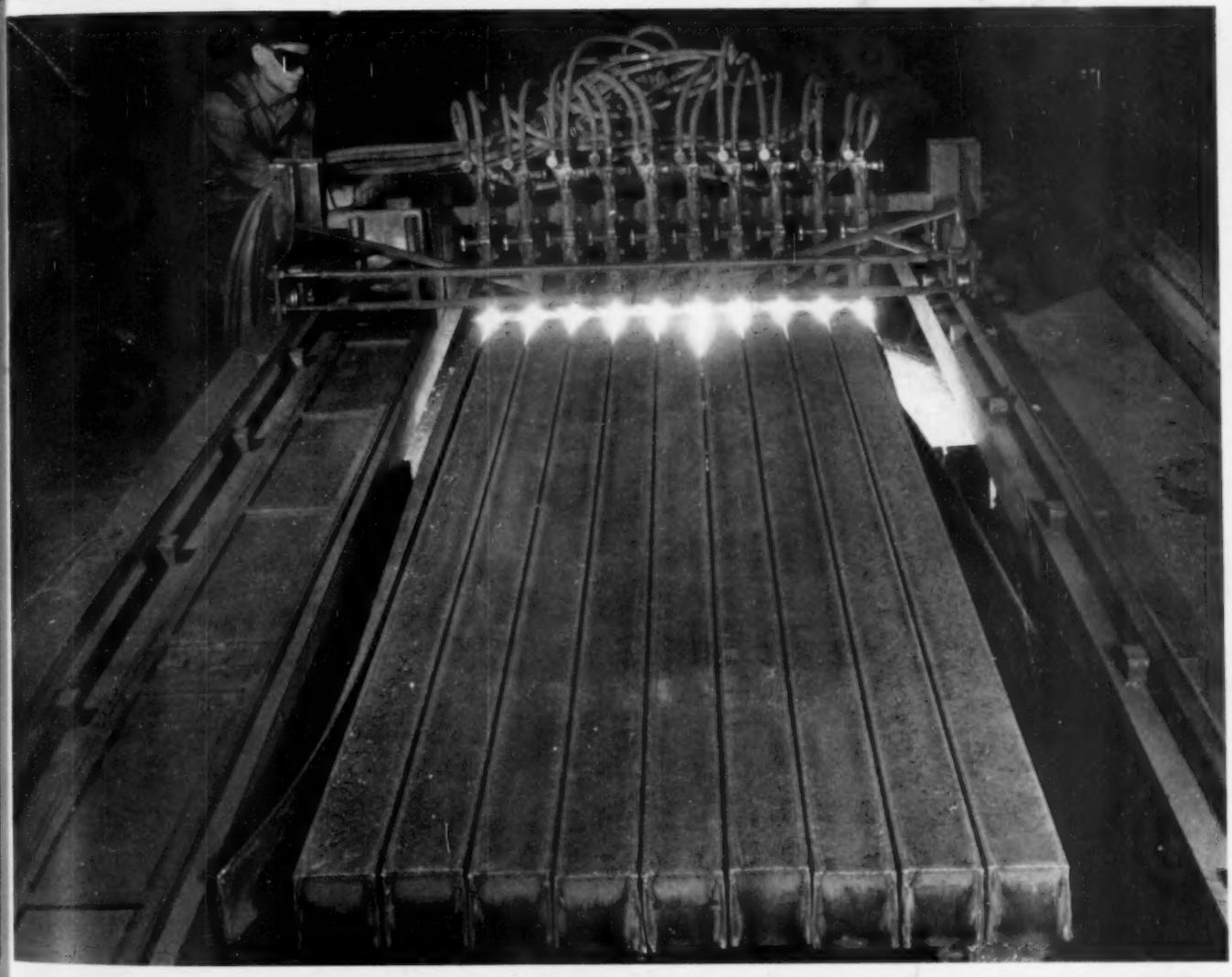
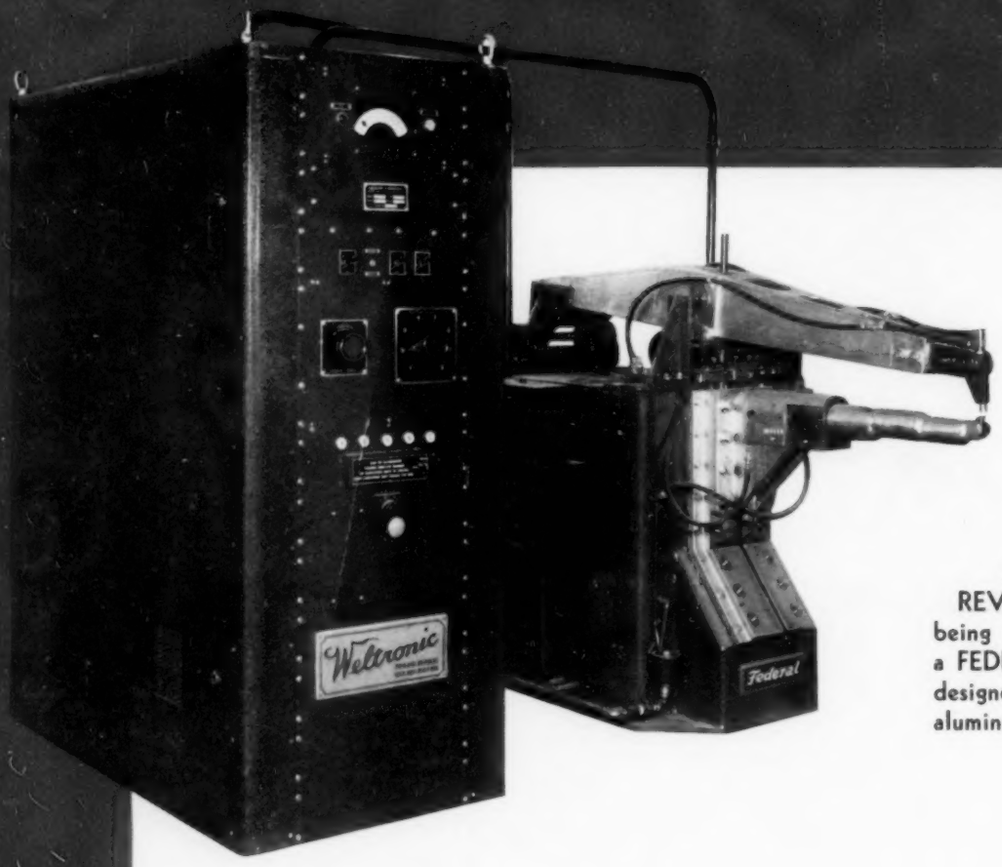
The WELDING Journal



The Journal of the American Welding Society



At Left, a Weltronic REVERS-O-CHARGE UNIT being used in combination with a FEDERAL rocker arm welder designed for welding of special aluminum aircraft parts.

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The Journal of

The American Welding Society

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Expansion and Contraction

By H. H. Griffith*

THE theory of expansion and contraction of metals is based on facts that are easily understood. When a body of any material is subjected to an increase in temperature it expands, that is, all its dimensions increase—the rate of this expansion being definitely known for each degree of rise of temperature. When the temperature is lowered a reverse action takes place. The body contracts and its dimensions decrease the same, amount, to all practical purposes, that they increased when the body was heated. Metals or metallic bodies are extremely susceptible to this change in dimensions caused by variations in temperature.

Effects of Expansion and Contraction

The effects of expansion and contraction are of great importance to the welding operator. These forces cannot be eliminated, arrested or mechanically controlled. Unless the operator has an appreciation of their nature it is impossible for him to produce satisfactory work. He must have a working knowledge of the amount of expansion and contraction usually encountered and the ingenuity to counteract them.

In ductile metals, such as sheet aluminum, expansion is quite liable to produce warping or buckling of the piece, while in materials that are not ductile but are brittle, such as cast iron, the result of contraction or expansion, unless properly taken care of, is breakage.

Coefficient of Expansion

The rate of expansion of different metals is constant and the amount of expansion varies directly with the temperature—the greater the increase in temperature the greater the amount of expansion. Engineers and scientists refer to this property of metals as "coefficient of expansion," of which their definition is "the linear increase per unit of length produced by a unit increase in temperature." This is a rather high-sounding term with an equally high-sounding definition. Actually it is quite simple. It means that the coefficient of expansion is the amount that a metal will increase in length if its temperature is increased one degree Fahrenheit. This is a helpful thing for the welding operator to know as it enables him to visualize in advance what will happen when he heats a metal and he can thus make his plans for handling the job accordingly.

Different Coefficients for Different Metals

The coefficient of expansion varies materially with the different metals. As may be seen from the table, Fig. 1, aluminum expands the most of any of the metals commonly worked on in the welding shop. Then next in order are brass, bronze, copper, steel and cast iron. It will be noted that aluminum expands twice as much as steel. Consequently, it is necessary that this fact be carefully considered before starting an aluminum weld. While the expansion of steel is not so great, it exists to such an extent that its consideration cannot be neglected.

Coefficient of Expansion, and Melting Points of Metal

	Coefficient of Expansion, In.	Melting Point, ° F.
Aluminum	0.00001280	1220
Brass		
Cast	0.00001040	1710
Drawn	0.00001070	1710
Bronze	0.00000100	1625
Copper	0.00000923	1981
Haynes Stellite alloy (Grade No. 1)	0.00000860	2282
Steel, low carbon*	0.00000630	2714
Cast Iron	0.00000590	2250

* The physical properties of alloy steels vary widely with their compositions.

Fig. 1

Use of the data in this table will be helpful to the welding operator. By multiplying together the coefficient of expansion, the length, and the rise in temperature, he can determine how much expansion he will have to allow for. For example, suppose he wishes to know how much a 4-ft. long aluminum bar will increase in length (expand) if he heats it from a room temperature of 70 to 1200° F., which is just below its melting point:

Coefficient of expansion of aluminum = 0.0000128.
Rise in temperature = 1200 − 70 = 1130.
Length = 48 in.
Then, the expansion = 0.0000128 × 1130 × 48 = 0.7 in.

In other words, the 4-ft. long aluminum bar will have expanded or increased in length almost $^{3}/_{4}$ in. This is assuming that the bar is heated for its entire length. In making a weld the bar would probably be heated for only a few inches.

Counteracting the Forces

There are many ways of taking care of expansion and contraction. If the expansion can take place in all directions it will give the welding operator little trouble, as the piece will expand equally all over, and upon cooling will contract to almost its original shape and dimensions. If, however, the welding takes place at a point that is confined by various parts, or by the particular construction of the piece, it is necessary to resort to one of several possible expedients, such as preheating the entire piece; simultaneously heating opposing similar parts;

* The Linde Air Products Co., New York

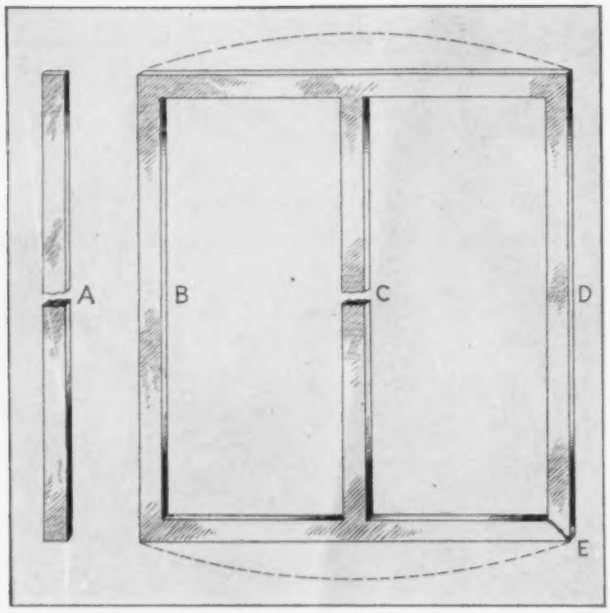


Fig. 2—The Expansion and Contraction of a Weld at C Might Be Counteracted by Several Different Methods

or cutting the piece at certain points to allow free expansion and then rewelding the cut after the original break has been welded. If the part is of a ductile or malleable metal, it may be manually warped or bent out of shape to such an extent that the spring will take care of the opposing force of contraction. This latter method however, often entails quite accurate calculations and therefore it is sometimes not feasible to use it.

Simplest Method

The simplest method and the one that most readily comes to the operator's mind, is that of heating the entire part to be welded to a dull red heat. When it is in this condition it is more or less flexible, that is, elastic, and any expansion stresses that may be set up in the weld, because of the extremely high temperature produced in the narrow zone of fusion, will be absorbed by the elasticity of the metal. Upon cooling, contraction will take place but as the entire part will shrink at about the same rate, any internal stress at the point of weld will be relieved.

More Difficult Problem

Let us now consider a more difficult problem but one that is representative. Assume that a long bar that is free at each end is broken at *A* as shown in Fig. 2. This weld may be executed without any fear of encountering difficulties due to expansion and contraction, since the bar is free at each end, as outlined above. But suppose that this bar is part of a rigid frame, with the break at *C*. It is quite obvious that it will now be necessary to take some measure to counteract the forces of expansion and contraction. Suppose further that is not practical or not desirable to preheat the frame all over.

It will readily be seen that expansion is not the force that will cause trouble because when the two pieces of the middle bar expand during welding, the metal, which is in a fused state, is so soft that the expansion will cause it to be upset. This will not affect the confined frame. Consider, however, what will happen when the metal starts to cool. Contraction will begin and the bar will shorten. If the metal is ductile and is one that will stand bending, such as steel, deformation or warping will occur. If it is non-malleable, such as cast iron, a break will occur either at the weld or at some other point of less resistance. It is imperative, therefore, that measures be taken to counteract or compensate for this shortening of the bar. There are two or three ways of doing this.

Other Ways of Handling

One way would be to preheat the two confining members of the frame at points *B* and *D*. This will cause these outside bars to expand and the edges of the break in the middle bar to separate. Therefore, when the weld is finished and the frame starts to cool and contract, bars *B* and *C*, inasmuch as they were raised to practically the same temperature as the metal surrounding the weld, will contract equally with bar *C*, thereby eliminating all the difficulty.

Another method of handling this job, if the frame is made of steel, would be to use jacks, wedges or similar devices to spring or bend the frame out of shape as indicated by the dotted lines, greatly exaggerated of course. This would separate the edges of the part to be welded. After the weld is executed and contraction begins, the jacks or wedges can be removed and in this way the return of the sprung parts to their original position will compensate for the contraction stresses.

Still another method would be to cut or break the frame at some extraneous point, such as at *E*. Then expansion and contraction will be free to act at point *C* without any fear of serious after effect, since the frame is free to spring in any direction because of the loose joint at *E*. As the point *E* is not confined, it will be an easy matter, as soon

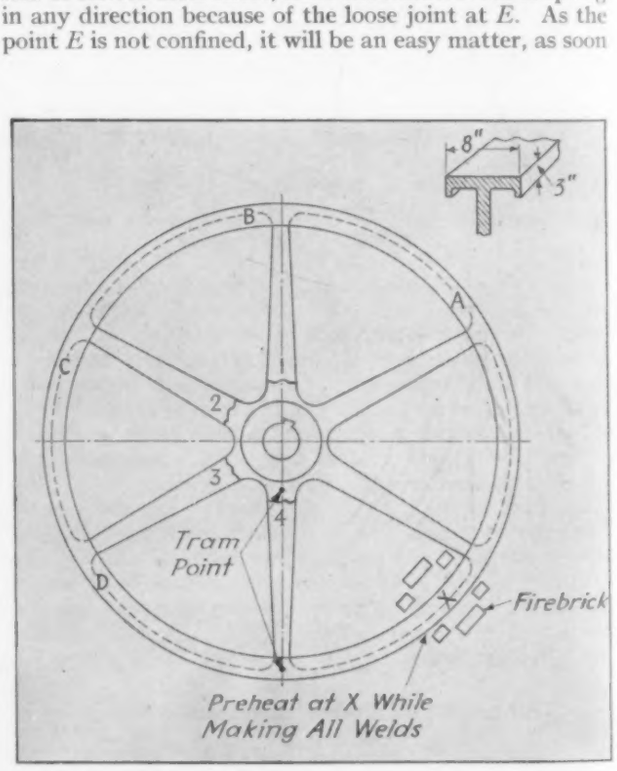


Fig. 3—This Cast-Iron Pulley Was Simultaneously Preheated at Two Opposing Points

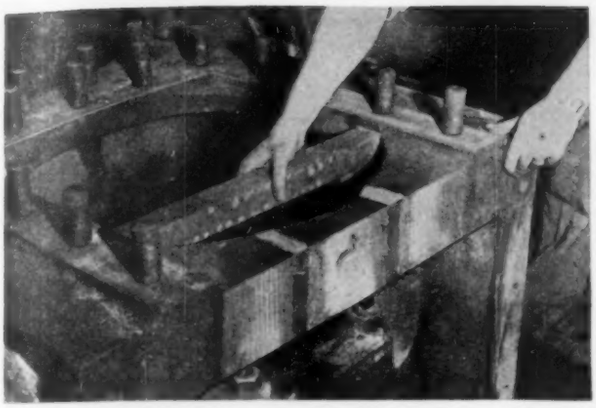


Fig. 4—An Adaptation of the Jack-Screw Method of Separating the Parts to Be Welded Was Used on This Casing

as the welding of the original break at *C* has been completed, to reweld this cut without fear of any bad results.

Practical Applications of Theory

While the frame described above is quite simple part, nevertheless, the principles to be considered and the methods of applying them in order to overcome the forces of contraction and expansion are identical with those experienced in all practical welding jobs, even those that at first glance appear quite complicated. Take, for example, the pulley shown in Fig. 3. Here the principle of simultaneously heating opposing parts was applied successfully—in fact it was applied not only once but four times in succession.

This cast-iron pulley is used in the power-transmission system of a canning factory. It is 48 in. in diameter with an 8-in. face. Four spokes were broken near the hub, as shown in the sketch. After the breaks were veed out and prepared for welding, the operator built two small firebrick preheating furnaces—one at *X* and one at *A* in the diagram. Kerosene preheating burners were used to heat the rim at these points to a dull red heat. This caused the metal to expand and the crack in spoke No. 1 to open up $^1/_8$ in., as measured with a tram between punch marks. The weld was then made with confidence that there would be no difficulties from the subsequent contraction.

After weld No. 1 was completed, the preheating furnace at *A* was moved to point *B* and No. 2 spoke was welded, then to point *C* and No. 3 was welded, and finally to point *D* for the No. 4 weld. During all of these successive welds the rim was kept preheated at *X*. Of course, if instead of four only one spoke had been broken, No. 4 for example, then the rim would have been preheated only at *X* and *D*, that is, at points near the spokes adjacent to the broken one.

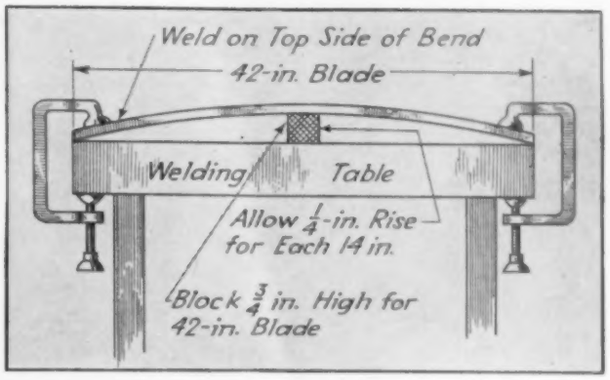


Fig. 5—This Is a Typical Application of the Reverse Bend Method

Mechanical Separation Method

An interesting adaptation of the principle of using a jack to separate mechanically the parts to be welded is shown in Fig. 4. The cast-iron valve housing of a steam engine was broken as illustrated. Instead of using an ordinary jack screw, a 2-in. square steel bar was placed just back of the damaged section and heated with the blowpipe until the face of the casting had been jacked apart $^1/_8$ in. by the force of expansion in the bar. The breaks were then bronze-welded without any difficulty.

Example of Bending Method

Another interesting application of the theory of expansion and contraction is found in connection with scraper blades for cleaning rolls used in flour-milling machinery. These blades, which are strips of steel $^3/_8$ in. thick, $2^3/_4$ in. wide and 42 in. long, are hard-faced with Haynes Stellite alloy to prevent excessive wear, the alloy being applied to the top side of the blade near the edge. The heat of applying the hard-facing rod tends to cause the blades to have a concave bow in them after cooling. To overcome this the blades are clamped at both ends to the welding table during the hard-facing operation, as shown in Fig. 5. A block is placed under the center of the blade to give it a reverse curve. The height of the curve is $^1/_4$ in. for each 14 in. of total length—or $^3/_4$ in. for a 42-in. blade. The C-clamps are removed immediately after welding is completed, and as the blade cools it returns to a flat position.

Study Each Job

A clear conception of the forces of expansion and contraction, and an understanding of the nature of their action and of how to counteract them are essential to successful welding. By giving a little thought and study to each individual job as it comes along, a practical method of handling it will soon be revealed.

Tentative Specifications for

IRON AND STEEL ARC-WELDING ELECTRODES[1]

Serial Designation: A 233 – 42 T

ISSUED, 1940; REVISED, 1942.[2]

This is a Tentative Standard and under the Regulations of the Cooperating Societies is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the A.S.T.M., 260 S. Broad Street, Philadelphia, Pa., or of the A.W.S., 33 W. 39th Street, New York, N. Y.

These specifications were prepared jointly by the American Welding Society and the American Society for Testing Materials.

Scope

1. (*a*) These specifications cover lightly coated and covered metal arc-welding electrodes for the welding of carbon and low alloy steels of weldable quality.

NOTE.—In connection with the welding of low alloy steels the requirements of these specifications pertain to the tensile strength and elongation of the deposited metal and not to high- or low-temperature characteristics, creep properties, or corrosion resistance.

(*b*) The electrodes are classified on the basis of usability and the ultimate tensile strength of all-weld-metal specimens in the stress-relieved condition, as shown in Table I.

Manufacture

2. The electrodes may be made by any methods that will yield a product conforming to the requirements of these specifications.

Standard Sizes and Lengths

3. Standard sizes and lengths of electrodes are as shown in the following table. In all cases, standard size refers to the diameter of the core wire.

Standard Sizes, Diameter of Core Wire, in.	Standard Lengths, in.
1/16	9 or 18[a]
3/32	12 or 18[a]
1/8 and 5/32	14
3/16	14 or 18
7/32, 1/4, 5/16, and 3/8	18

[a] In the case of 18-in. lengths of 1/16 and 3/32-in. electrodes, center gripping of the electrodes is standard. In all other cases, end gripping is standard.

Chemical Composition

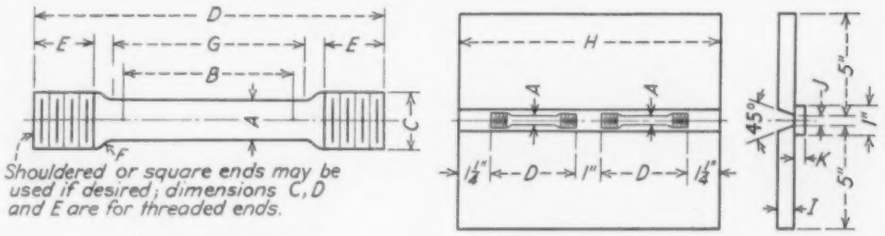
4. The electrodes shall be capable of depositing metal conforming to the following requirement as to chemical composition:

Sulfur, max., per cent	0.04

Chemical Analysis

5. The sample for analysis shall be prepared as follows: A specimen of standard base metal (see Section 6 (*a*) and (*b*)) of sufficient size, shall be prepared, and a pad of five superimposed layers of weld metal deposited thereon. The fifth or top layer shall be ground or machined away and discarded. The sample for chemical analysis shall be obtained from the third and fourth layers.

Electrode Size, in.	Test Plate Thickness, in. I	Number of Layers	Diameter of Tension Test Specimen, in. A	Dimensions of Test Plate and Tension Test Specimen, in. B	C	D	E	F	G	H	J	K
1/16	1/2	Each Layer or Pass not to Exceed 3/8 in. in Thickness.	0.252 ± 0.005	1	3/4	2 1/2	1/2	3/8	1 1/4	8 1/2	3/4	3/8
5/32	3/4		0.500 ± 0.01	2	3/4	4 1/4	3/4	5/8	2 1/4	12	1/2	1/4
7/16	3/4		0.500 ± 0.01	2	3/4	4 1/4	3/4	5/8	2 1/4	12	1/2	1/4
1/32	3/4		0.500 ± 0.01	2	3/4	4 1/4	3/4	5/8	2 1/4	12	1/2	1/4
1/4	1		0.500 ± 0.01	2	3/4	4 1/4	3/4	5/8	2 1/4	12	1/2	1/2
5/16	1 1/4		0.500 ± 0.01	2	3/4	4 1/4	3/4	5/8	2 1/4	12	1/2	1/2
3/8	1 1/2		0.500 ± 0.01	2	3/4	4 1/4	3/4	5/8	2 1/4	12	1/2	1/2



Tension Test Specimen. Test Plate Showing Location of Test Specimens.

FIG. 1.—Requirements for Preparation of Tension Test Specimens.

All-Weld-Metal Tension Tests

6. Tension tests shall be made as prescribed in the following Paragraphs (*a*) to (*g*):

(*a*) For testing electrodes of the E45, E60, and E70 classifications, the steel to be used for test plates shall conform to either of the following specifications of the American Society for Testing Materials:

(*1*) Standard Specifications for Carbon-Steel Plates for Stationary Boilers and other Pressure Vessels (A.S.T.M. Designation: A 70).[3]

(*2*) Standard Specifications for Steel for Bridges and Buildings (A.S.T.M. Designation: A 7),[4] open-hearth or electric-furnace steel.

(*b*) For testing electrodes of the E80, E90, and E100 classifications, the steel to be used for test plates shall conform to one of the following specifications of the American Society for Testing Materials, or shall be a similar steel containing not over 0.30 per cent carbon and having a minimum tensile strength of 75,000 psi.

(*1*) Standard Specifications for Low-Carbon Nickel-Steel Plates for Boilers

[1] Under the standardization procedure of the two Societies, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel, and of the A.W.S. Filler Metal Specifications Committee.

[2] Revision accepted by A.S.T.M. Committee E-10 on Standards, April 28, 1942; approved by A.W.S. Board of Directors, May 7, 1942.

These specifications which comprise a portion of the former Tentative Specifications for Iron and Steel Filler Metal (Arc-Welding Electrodes and Gas-Welding Rods (A 205 – 37 T)) were published as tentative from 1937 to 1940.

[3] 1939 Book of A.S.T.M. Standards, Part I, p. 41.

[4] *Ibid.*, p. 1.

and Other Pressure Vessels (A.S.T.M. Designation: A 203),[5] grade C.

(*2*) Standard Specifications for

has been tacked, the assembly shall be heated in boiling water for 5 min. prior to welding. After depositing each pass,

TABLE I.—TENSILE REQUIREMENTS OF DEPOSITED METAL.

Metal (Arc-Welding Electrodes and Gas-Welding Rods (A 205 – 37 T)) were published as tentative from 1937 to 1940.

depositing metal conforming to the fol-

to be used for test plates shall conform

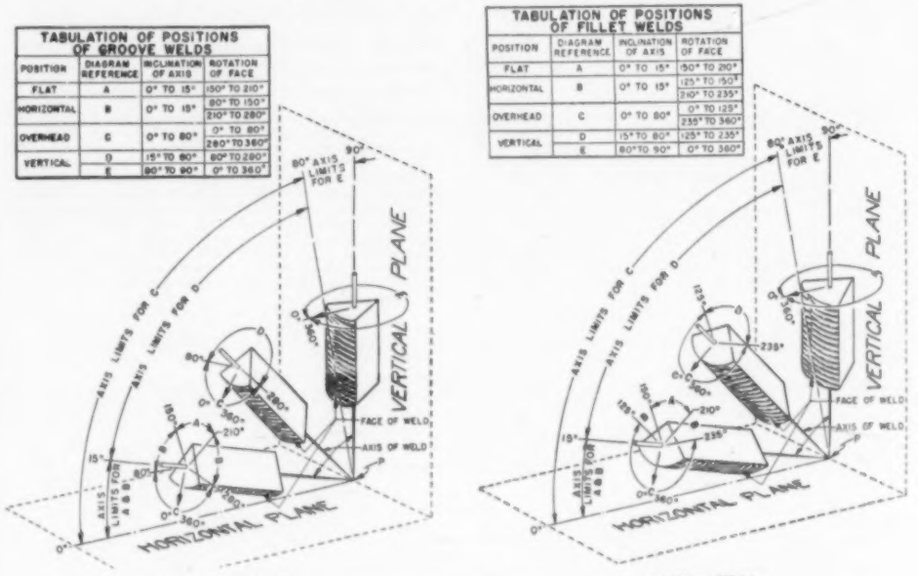
[5] 1939 Book of A.S.T.M. Standards, Part I, p. 41.
[6] *Ibid.*, p. 1.

and Other Pressure Vessels (A.S.T.M. Designation: A 203),[5] grade C.

(*2*) Standard Specifications for Molybdenum-Steel Plates for Boilers and Other Pressure Vessels (A.S.T.M. Designation: A 204),[6] grade C.

(*c*) For electrodes smaller than $\frac{1}{8}$ in., the all-weld-metal tension test is not

has been tacked, the assembly shall be heated in boiling water for 5 min. prior to welding. After depositing each pass, the assembly shall be left on the asbestos to cool in still air for 10 min., and then immersed in boiling water for 5 min. Each subsequent pass shall be deposited immediately after removal from boiling


TABULATION OF POSITIONS OF GROOVE WELDS
POSITION | DIAGRAM REFERENCE | INCLINATION OF AXIS | ROTATION OF FACE
FLAT | A | 0° TO 15° | 150° TO 210°
HORIZONTAL | B | 0° TO 15° | 80° TO 150° 210° TO 280°
OVERHEAD | C | 0° TO 80° | 0° TO 80° 280° TO 360°
VERTICAL | D | 15° TO 80° | 80° TO 280°
VERTICAL | E | 80° TO 90° | 0° TO 360°
TABULATION OF POSITIONS OF FILLET WELDS
POSITION | DIAGRAM REFERENCE | INCLINATION OF AXIS | ROTATION OF FACE
FLAT | A | 0° TO 15° | 150° TO 210°
HORIZONTAL | B | 0° TO 15° | 125° TO 150° 210° TO 235°
OVERHEAD | C | 0° TO 80° | 0° TO 125° 235° TO 360°
VERTICAL | D | 15° TO 80° | 125° TO 235°
VERTICAL | E | 80° TO 90° | 0° TO 360°
AXIS LIMITS FOR C
AXIS LIMITS FOR D
AXIS LIMITS FOR E
AXIS LIMITS FOR A OR B
VERTICAL PLANE
HORIZONTAL PLANE
FACE OF WELD
AXIS OF WELD

(*a*) Groove Welds. (*b*) Fillet Welds.

The horizontal reference plane is taken to lie always below the weld under consideration.
Inclination of axis is measured from the horizontal reference plane toward the vertical.
Angle of rotation of face is measured from a line perpendicular to the axis of the weld and lying in a vertical plane containing this axis. The reference position (0 deg.) of rotation of the face invariably points in the direction opposite to that in which the axis angle increases. The angle of rotation of the face of weld is measured in a clockwise direction from this reference position (0 deg.) when looking toward point "*P*".

FIG. 2.—Position of Welds.

practical and the strength of these sizes shall be judged by the strength of $\frac{1}{8}$-in. or larger electrodes of the same classification.

(*d*) For electrodes $\frac{1}{8}$ in. and larger a test plate shall be prepared as shown in Fig. 1. The plate shall be insulated from the welding bench by $\frac{1}{2}$ in. of asbestos during welding. After the joint

water. After the last pass, the assembly shall be removed from boiling water after the 5-min. period. If it is necessary to interrupt the pass sequence prescribed above, the assembly shall be removed from boiling water after a 5-min. period and allowed to cool in still air at room temperature. When ready to resume work, the assembly shall be preheated in boiling water for a period of 5 min. The work shall be done at room temperature of not less

[5] 1939 Book of A.S.T.M. Standards, Part I, p. 69.
[6] *Ibid.*, p. 73.

TABLE I.—TENSILE REQUIREMENTS OF DEPOSITED METAL.

Electrode Classification Number	Capable of Producing Satisfactory Welds in Positions Shown[a]	General Description	Treatment of Welded Specimen[b]	Tension Test Requirements of Material Deposited from $\frac{1}{4}$ to $\frac{5}{16}$-in. Electrodes[c]		
				Tensile Strength, min., psi.	Yield Point, min., psi.	Elongation in 2 in., min., per cent
E4510	F, V, OH, H	Wire with coating applied before drawing.	NSR	45 000	.....	5
E4511	F, V, OH, H	Wire with light coating applied after drawing.	NSR	45 000	.....	5
E4520	H-Fillets, F	Wire with coating applied before drawing.	NSR	45 000	.....	5
E4521	H-Fillets, F	Wire with light coating applied after drawing.	NSR	45 000	.....	5
E6010	F, V, OH, H	Heavy covering, useful with d.c., electrode positive only.	SR NSR	60 000 62 000	47 000 52 000	27 22
E6011	F, V, OH, H	Heavy covering, useful with a.c. only.	SR NSR	60 000 62 000	47 000 52 000	27 22
E6012	F, V, OH, H	Heavy covering, usually used with electrode negative, d.c. or on a.c.	SR NSR	60 000 62 000	47 000 52 000	22 17
E6013	F, V, OH, H	Heavy covering, usually used on a.c.	SR NSR	60 000 62 000	47 000 52 000	22 17
E6020	H-Fillets, F	Heavy covering, usually used with electrode negative or a.c. for fillets, and electrode positive or a.c. for flat welding.	SR NSR	60 000 62 000	47 000 52 000	30 25
E6030	F	Heavy covering, usually used with electrode positive on d.c., or with a.c.	SR NSR	60 000 62 000	47 000 52 000	30 25
E7010	V, F, OH, H	Heavy covering, useful with d.c., electrode positive only.	SR NSR	70 000 72 000	57 000 62 000	22 17
E7011	F, V, OH, H	Heavy covering, useful with a.c. only.	SR NSR	70 000 72 000	57 000 62 000	22 17
E7012	F, V, OH, H	Heavy covering, usually used with electrode negative, d.c. or on a.c.	SR NSR	70 000 72 000	57 000 62 000	20 15
E7020	H-Fillets, F	Heavy covering, usually used with electrode negative or a.c. for fillets, or electrode positive or a.c. for flat welding.	SR NSR	70 000 72 000	57 000 62 000	25 20
E7030	F	Heavy covering, usually used with electrode positive d.c., or with a.c.	SR NSR	70 000 72 000	57 000 62 000	25 20
E8010	F, V, OH, H	Heavy covering, useful with d.c. electrode positive only.	SR	80 000	67 000	19
E8011	F, V, OH, H	Heavy covering, useful with a.c. only.	SR	80 000	67 000	19
E8012	F, V, OH, H	Heavy covering, usually used with electrode negative, d.c. or on a.c.	SR	80 000	67 000	17
E8020	H-Fillets, F	Heavy covering, usually used with electrode negative or a.c. for fillets, or electrode positive or a.c. for flat welding.	SR	80 000	67 000	22
E8030	F	Heavy covering, usually used with electrode positive d.c., or with a.c.	SR	80 000	67 000	22

TABLE I.—*Concluded.*

Electrode Classification Number	Capable of Producing Satisfactory Welds in Positions Shown[a]	General Description	Treatment of Welded Specimen[b]	Tension Test Requirements of Material Deposited from 1/8 to 5/32-in. Electrodes[c]		
				Tensile Strength, min., psi.	Yield Point, min., psi.	Elongation in 2 in., min., per cent
E9010	F, V, OH, H	Heavy covering, useful with d.c. electrode positive only.	SR.....	90 000	77 000	18
E9011	F, V, OH, H	Heavy covering, useful with a.c. only.	SR.....	90 000	77 000	18
E9012	F, V, OH, H	Heavy covering, usually used with electrode negative, d.c. or on a.c.	SR.....	90 000	77 000	16
E9020	H-Fillets, F	Heavy covering, usually used with electrode negative or a.c. for fillets, or electrode positive or a.c. for flat welding.	SR.....	90 000	77 000	20
E9030	F	Heavy covering, usually used with electrode positive d.c., or with a.c.	SR.....	90 000	77 000	20
E10010	F, V, OH, H	Heavy covering, useful with d.c. electrode positive only.	SR.....	100 000	87 000	16
E10011	F, V, OH, H	Heavy covering, useful with a.c. only.	SR.....	100 000	87 000	16
E10012	F, V, OH, H	Heavy covering, usually used with electrode negative, d.c. or on a.c.	SR.....	100 000	87 000	14
E10020	H-Fillets, F	Heavy covering, usually used with electrode negative or a.c. for fillets, or electrode positive or a.c. for flat welding.	SR.....	100 000	87 000	18
E10030	F	Heavy covering, usually used with electrode positive d.c., or with a.c.	SR.....	100 000	87 000	18

[a] The abbreviations F, V, H, OH, and H-Fillets indicate welding positions, as follows:
F—Flat, H—Horizontal,
V—Vertical, OH—Overhead, and
H-Fillets—Horizontal Fillets.

[b] The abbreviations SR and NSR signify stress-relieved and non-stress-relieved, respectively. Stress-relieving when prescribed in these specifications is for the purpose of developing the fundamental properties of the weld metal unaltered by locked-up stress. Values obtained from stress-relieved welded specimens are about 5 per cent lower in tensile strength and 10 to 20 per cent higher in elongation than those of non-stress-relieved specimens. The fact that an electrode test requires stress-relief signifies only that it must develop the strength required regardless of stress-relief, and not that stress-relief must always be used in actual work. Stress-relieving shall be within the range of 1150 ± 25 F. for 1 hr. per inch of thickness. Specimens shall be heated in a suitable furnace at the rate of 300 to 350 F. per hour until a temperature of 1150 ± 25 F. has been attained. After this temperature has been reached, it shall be maintained for 1 hr. for each inch or fraction thereof of the maximum thickness of the section. The specimens shall be cooled at the same rate specified for heating and may be removed from the furnace when the temperature of the plates has reached 300 F.

[c] The tension test requirements of material deposited from 3/16-in. electrodes shall be the same as that indicated for 1/8 to 5/32-in. electrodes, except that the tensile strength and yield point shall be 95 per cent of that prescribed in Table I.

than 60 F. and in the flat position. Weaving shall be the full width of the groove except for the last layer, which shall be deposited in two passes. Test plates shall preferably be so supported that warping due to welding will not cause the finished test plate to be out of line by more than 5 deg. If test plates become warped more than 5 deg. they shall be straightened cold before being stress-relieved when required.

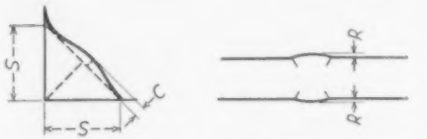
(*e*) Two all-weld-metal tension test specimens shall be machined from the finished test plate as shown in Fig. 1, and shall conform to the requirements as to tensile properties prescribed in Table I.

(*f*) If either specimen fails, another test plate shall be welded and both specimens shall conform to the requirements as to tensile properties prescribed in Table I.

(*g*) Electrodes in each classification shall be capable of producing satisfactory welds which will conform to the all-weld-metal tension test requirements prescribed in Table I, for the types of current and the welding positions listed in the table. Welding positions shall be determined from Fig. 2.

Weld Contour Tests

7. (*a*) For each classification and size of electrode, specimen butt and fillet welds shall be prepared with the types of current and the welding positions listed in Table I. The size and convexity of fillet welds and the height of



(*a*) Fillet Weld Profile. (*b*) Butt Weld Profile.

FIG. 3.—Acceptable Fillet and Butt Weld Profiles.

reinforcement of butt welds shall be measured (see Fig. 3) and shall conform to the following requirements: For fillet welds the convexity shall not exceed $0.1S + 0.03$ in., where S is the size of the fillet weld in inches; for butt welds the height of reinforcement shall be not less than $\frac{1}{32}$ in. and not more than $\frac{1}{8}$ in.

(*b*) The results shall be recorded and shall be furnished by the manufacturer to the purchaser upon request.

Face- and Root-Bend Tests of Welded Joints

8. For electrodes of the E60 and E70 classifications, face- and root-bend tests shall be made as prescribed in the following Paragraphs (*a*) to (*f*):

(*a*) The steel to be used for test plates shall conform to either of the specifications listed in Section 6 (*a*).

(*b*) For each classification of electrode, a test plate as shown in Fig. 4 shall be prepared in each position for which the electrode is suitable, as listed in Table I. The work shall be done at room temperature of not less than 60 F. No stress-relieving shall be performed on the test plate or on the specimens removed therefrom.

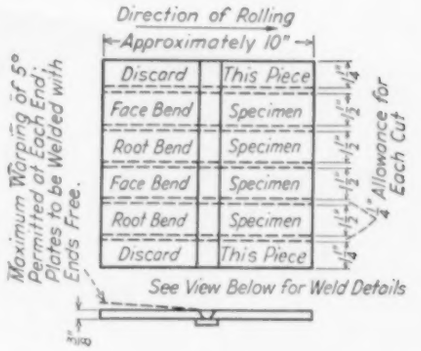


FIG. 4.—Requirements for Preparation of Test Plate for Face- and Root-Bend Tests.

(*c*) From each test plate there shall be removed two face-bend specimens and two root-bend specimens in the order shown in Fig. 4. The specimens shall be prepared for testing as shown in Fig. 5.

(*d*) Each specimen shall be bent in a jig having the working contour shown in Fig. 6, and otherwise substantially in accordance with that figure. Any convenient means may be used for moving

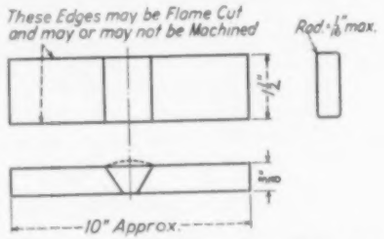
the plunger member with relation to the die member. The specimen shall be

and the welding positions for which the electrodes are suitable, as listed in

concentricity shall be measured by any suitable means, such as the following:

from injurious scabs, blisters, abnormal pockmarks, bruises, or other surface de-

the plunger member with relation to the die member. The specimen shall be placed on the die member of the jig with the weld at midspan. Face-bend specimens shall be placed with the face of the weld directed toward the gap and root-bend specimens shall be placed with the root of the weld directed toward the gap. The two members of the jig shall be forced together until the specimen conforms to a U-shape, and until a wire $\frac{1}{32}$ in. in diameter cannot be placed between the specimen and any point on the curvature of the plunger member of the jig. The



NOTE.—Weld reinforcement shall be removed flush with the surface of the specimen. Machining shall be done lengthwise of the specimen. The surface of the specimen to be tested shall be finely machined or ground.

FIG. 5.—Face- and Root-Bend Test Specimens.

specimen shall then be removed from the jig.

(*e*) The convex surface of each specimen shall be examined for the appearance of cracks or other open defects. The specimen shall be considered as having failed if a crack or other open defect, exceeding $\frac{1}{8}$ in. measured in any direction, is present after the bending. Cracks occurring on the corners of the specimen during testing shall not be considered.

(*f*) Electrodes of all sizes in each E60 and E70 classification shall be capable of producing satisfactory welds which will conform to the face- and root-bend test requirements prescribed in Paragraphs (*a*) to (*e*) above, for the types of current and the welding positions for which the electrodes are suitable, as listed in Table I.

Permissible Variations in Dimensions

9. (*a*) Covered electrodes for manual welding shall be bare or free from covering for a distance of about 1 in., but not more than $1\frac{1}{4}$ in., for making contact with the holder.

(*b*) The arc end of each electrode shall be sufficiently bare to permit easy striking of the arc, but the length of the bare

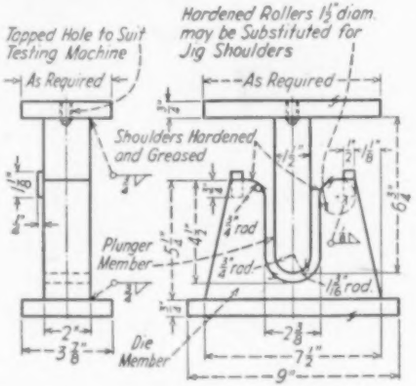


FIG. 6.—Guided-Bend Test Jig.

portion of the arc end, measured from the end to the point where the full cross-section of the coating obtains, shall not exceed one core-wire diameter or in any case be more than $\frac{3}{8}$ in.

(*c*) The diameter of the core wire shall not vary more than plus or minus 0.002 in. from the standard size specified. The length shall not vary more than plus or minus $\frac{1}{8}$ in. from that specified.

(*d*) The covering on covered electrodes of all sizes shall be concentric to the extent that the maximum core-plus-one-covering dimension shall not exceed the minimum core-plus-one-covering dimension by more than 3 per cent. The concentricity shall be measured by any suitable means, such as the following:

The covering shall be removed from one side of the electrode (care being taken to insure that no metal is removed from the core) at about the middle of its length. The core-plus-one-covering dimension (which is the diameter of the core plus the thickness of the covering on one side) shall be measured with a micrometer. The covering shall be removed from the opposite side of the electrode at a point distant from the place where the covering was previously removed, and a similar measurement made. Two more pairs of measurements of the core-plus-one-covering dimension shall be made on planes at angles of 60 and 120 deg. from the plane of the former measurements. The pair of measurements which shows the greatest percentage of variation shall be used in determining the acceptability of the electrode.

Electrode Coverings

10. (*a*) The coverings shall, when cool, have sufficient electrical resistance to effectively insulate against a difference of potential of 100 v.

(*b*) The slag produced shall be readily removable.

Workmanship

11. (*a*) Lightly coated electrodes and the core of covered electrodes shall be of uniform quality and free from injurious segregation, oxides, pipe, seams, or other irregularities.

(*b*) On covered electrodes, the coverings shall be such that they are not readily damaged by ordinary handling and shall be of commercially uniform thickness and shall present a workmanlike appearance. Coverings shall be free from injurious scabs, blisters, abnormal pockmarks, bruises, or other surface defects.

Finish

12. The surface of lightly coated electrodes and the core of covered electrodes shall be smooth and free from harmful scale, oil, or grease.

Packing

13. Electrodes shall be suitably packed, wrapped, boxed, or crated to insure against injury during shipment or storage, as follows:

(*a*) Bundles of 50 lb. net weight,

(*b*) Boxes of 25 or 50 lb. net weight, and

(*c*) Coils or reels of approximately 150 or 200 lb. net weight.

Marking

14. All bundles, boxes, coils, or reels shall be legibly marked with the following information:

(*a*) Classification,

(*b*) Manufacturer's name and trade designation,

(*c*) Standard size and length, (weight instead of length in case of reels and coils), and

(*d*) Guarantee.

Guarantee

15. The manufacturer shall make tests at frequent intervals in accordance with the methods prescribed in these specifications, and shall guarantee that the electrodes in all sizes and classes conform to these specifications and each container shall be so marked. The manufacturer's responsibility shall be limited to replacement of any electrodes which do not conform to the requirements of these specifications.

Tentative Specifications for

IRON AND STEEL GAS-WELDING RODS[1]

Serial Designation: A 251 - 42 T

ISSUED, 1942[2]

This is a Tentative Standard and under the Regulations of the Cooperating Societies is subject to annual revision. Suggestions for revision should be addressed to the Headquarters of the A.S.T.M., 260 S. Broad Street, Philadelphia, Pa., or of the A.W.S., 33 W. 39th Street, New York, N. Y.

These Specifications were prepared jointly by the American Welding Society and the American Society for Testing Materials.

Scope

1. (*a*) These specifications cover gas-welding rods for the welding of carbon and low-alloy steels of weldable quality.

NOTE.—In connection with the welding of low-alloy steels the requirements of these specifications pertain to the tensile strength and elongation of the deposited metal and not to high- or low-temperature characteristics, creep properties, or corrosion resistance.

(*b*) The rods are classified on the basis of the ultimate tensile strength of the deposited weld metal in the stress-relieved condition, as shown in Table I.

Manufacture

2. The rods may be made by any methods that will yield a product conforming to the requirements of these specifications.

Standard Sizes and Length

3. Standard length rods are 36 in., and standard diameters are as follows:

$\frac{1}{16}$ in.	$\frac{5}{32}$ in.	$\frac{5}{16}$ in.
$\frac{3}{32}$ in.	$\frac{3}{16}$ in.	$\frac{3}{8}$ in.
$\frac{1}{8}$ in.	$\frac{1}{4}$ in.	

Chemical Composition

4. The rods shall conform to the following requirement as to chemical composition:

Sulfur, max., per cent	0.045

Tension Tests

5. Tension tests shall be made, using $\frac{3}{16}$ or $\frac{1}{4}$-in. welding rods, as prescribed in the following Paragraphs (*a*) to (*e*), these tests qualifying all sizes of welding rod made from the same melt of steel.

(*a*) The steel to be used for test plates shall conform to either of the following specifications of the American Society for Testing Materials:

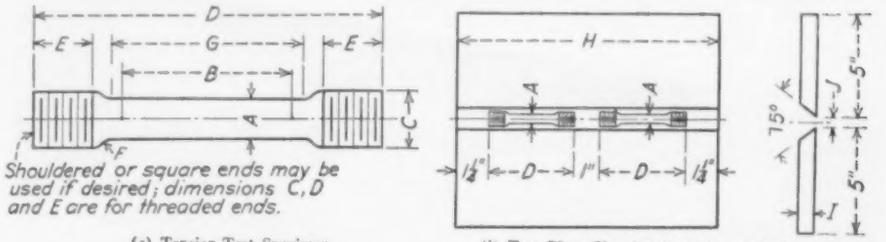
(*1*) Standard Specifications for Carbon-Steel Plates for Stationary Boilers and other Pressure Vessels (A.S.T.M. Designation: A 70),[3] and

(*2*) Standard Specifications for Steel for Bridges and Buildings (A.S.T.M. Designation: A 7),[4] open-hearth or electric-furnace steel.

(*b*) A test plate shall be prepared as shown in Fig. 1 (for welding rods of the GA65, GA60, GA50, GB65, and GB60 classifications) or Fig. 2 (for welding rods of the GB45 classification). The plate shall be insulated from the welding bench by asbestos during welding. After the joint has been tacked, the plate on both sides of the joint shall be heated for approximately 5 min. with a flame of the size and type to be used in welding the joint. The test plate shall then be welded using a maximum of five layers and having no layer exceeding $\frac{5}{16}$ in. in thickness. The weld metal shall be deposited with a backhand technique,

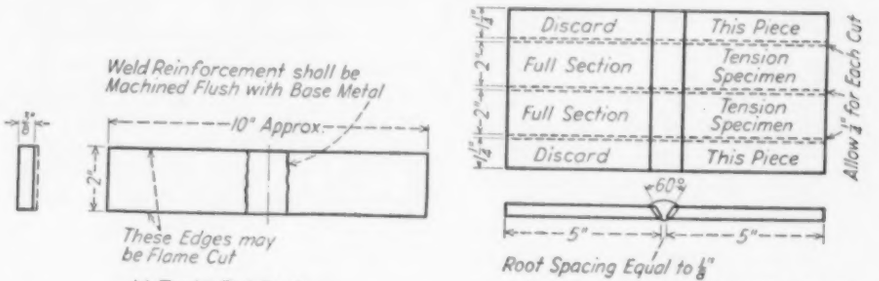
Dimensions of Test Plate and Tension Test Specimen, in.

A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
0.500 ± 0.01	2	¾	4¼	¾	⅝	2¼	12	¾	¾



(*a*) Tension Test Specimen. (*b*) Test Plate Showing Location of Test Specimens.

FIG. 1.—Requirements for Preparation of All-Weld-Metal Tension Test Specimens.



(*a*) Tension Test Specimen. (*b*) Test Plate Showing Location of Test Specimen

FIG. 2.—Requirements for Preparation of Full-Section Tension Test Specimens.

[1] Under the standardization procedure of the two Societies, these specifications are under the jurisdiction of the A.S.T.M. Committee A-1 on Steel, and of the A.W.S. Filler Metal Specifications Committee.

[2] Accepted by A.S.T.M. Committee E-10 on Standards, April 28, 1942; approved by A.W.S. Board of Directors, May 7, 1942.

These specifications which comprise a portion of the former Tentative Specifications for Iron and Steel Filler Metal (Arc-Welding Electrodes and Gas-Welding Rods (A 205 – 37 T)) were published as tentative from 1937 to 1940.

[3] 1939 Book of A.S.T.M. Standards, Part I, p. 41.

[4] *Ibid.*, p. 1.

using the size and type of flame recom-

Face- and Root-Bend Tests of Welded Joints

(*b*) A test plate shall be prepared as shown in Fig. 3. The work shall be

forms to a U-shape, and until a wire $\frac{1}{32}$ in. in diameter cannot be placed be-

Metal (Arc-Welding Electrodes and Gas-Welding Rods (A 208 – 37 T)) were published as tentative from 1937 to 1940.

shall conform to either of the following

[2] 1939 Book of A.S.T.M. Standards, Part I, p. 41.
[3] *Ibid.*, p. 3.

deposited with a backhand technique,

using the size and type of flame recommended by the manufacturer of the welding rod. After depositing each layer, the plate shall be left on the asbestos to cool in still air for at least 15 min. The joint shall be welded completely but shall not have a reinforcement exceeding 20 per cent of the plate thickness. It is permissible to torch normalize the weld by reheating the weld metal above the critical temperature range. After the last pass, the plate shall be left on the asbestos until cold. The work shall be done at room temperature of not less than 60 F. and in the flat position. Test plates shall preferably be so supported that warping due to welding will not cause the finished test plate to be out of line by more than 5 deg. If test plates become warped more than 5 deg. they shall be straightened cold before being stress-relieved, when required.

(*c*) Two tension test specimens shall be machined from the finished test plate as shown in Fig. 1 (for welding rods of the GA65, GA60, GA50, GB65, and GB60 classifications) or Fig. 2 (for welding rods of the GB45 classification), and shall conform to the requirements as to tensile properties prescribed in Table I.

(*d*) If either specimen fails, another test plate shall be welded and both specimens shall conform to the tension test requirements prescribed in Table I.

(*e*) Welding rods in each classification shall be capable of producing satisfactory welds which will conform to the tension test requirements prescribed in Table I for all positions of welding.

Face- and Root-Bend Tests of Welded Joints

6. For all classifications of welding rods, except GB45, face- and root-bend

TABLE I.—TENSILE REQUIREMENTS OF DEPOSITED METAL.

(Using 5/32 or 1/4-in. Welding Rods)

Welding Rod Classification Number	Plate Thickness, in.	Treatment of Welded Specimen[a]	Tension Test Requirements	
			Tensile Strength, min., psi.	Elongation in 2 in., min., per cent
GA65	3/4	SR	65 000	20
		NSR	72 000	17
GA60	3/4	SR	60 000	25
		NSR	62 000	20
GA50	3/4	SR	50 000	28
		NSR	52 000	23
GB65	3/4	SR	65 000	18
		NSR	72 000	15
GB60	3/4	SR	60 000	20
		NSR	62 000	15
GB45	3/4	NSR	45 000[b]	..

[a] The abbreviations SR and NSR signify stress-relieved and non-stress-relieved, respectively. Stress-relieving when prescribed in these specifications is for the purpose of developing the fundamental properties of the weld metal unaltered by locked-up stress. Values obtained from stress-relieved welded specimens are about 5 per cent lower in tensile strength and 10 to 20 per cent higher in elongation than those of non-stress-relieved specimens. Stress-relieving shall be within the range of 1150 ± 25 F. for 1 hr. per inch of thickness. Specimens shall be heated in a suitable furnace at the rate of 300 to 350 F. per hour until a temperature of 1150 ± 25 F. has been attained. After this temperature has been reached, it shall be maintained for 1 hr. for each inch or fraction thereof of the maximum thickness of the section. The specimens shall be cooled at the same rate specified for heating and may be removed from the furnace when the temperature of the plates has reached 300 F.

[b] This value shall be obtained with the full-section tension test specimen shown in Fig. 2. All other values in this column shall be obtained with the all-weld-metal tension test specimen shown in Fig. 1.

tests shall be made, using $\frac{3}{16}$ or $\frac{1}{4}$-in. welding rods, as prescribed in the following Paragraphs (*a*) to (*f*), these tests qualifying all sizes of welding rod made from the same melt of steel.

(*a*) The steel to be used for test plates shall conform to either of the specifications listed in Section 5 (*a*).

(*b*) A test plate shall be prepared as shown in Fig. 3. The work shall be done at room temperature of not less than 60 F. and in the flat position. No stress-relieving shall be performed on the test plate or on the specimens removed therefrom.

(*c*) From each test plate there shall be removed two face-bend specimens and two root-bend specimens in the order shown in Fig. 3. The specimens shall be prepared for testing as shown in Fig. 4.

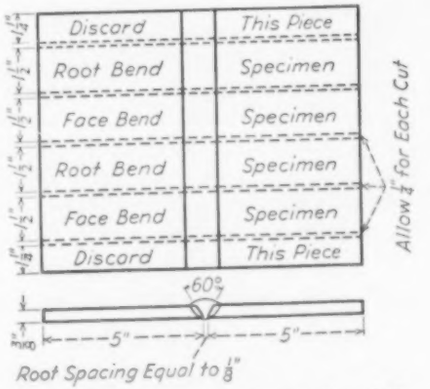
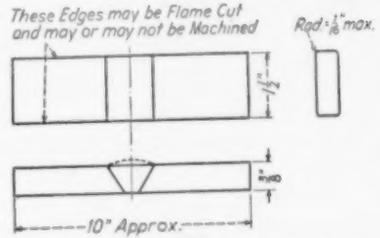


FIG. 3.—Requirements for Preparation of Test Plate for Face- and Root-Bend Tests.

(*d*) Each specimen shall be bent in a jig having the working contour shown in Fig. 5, and otherwise substantially in accordance with that figure. Any convenient means may be used for moving the plunger member with relation to the die member. The specimen shall be placed on the die member of the jig with the weld at mid-span. Face-bend specimens shall be placed with the face of the weld directed toward the gap, and root-bend specimens shall be placed with the root of the weld directed toward the gap. The two members of the jig shall be forced together until the specimen conforms to a U-shape, and until a wire $\frac{1}{32}$ in. in diameter cannot be placed between the specimen and any point on the curvature of the plunger member of the jig. The specimen shall then be removed from the jig.



NOTE.—Weld reinforcement shall be removed flush with the surface of the specimen. Machining shall be done lengthwise of the specimen. The surface of the specimen to be tested shall be finely machined or ground.

FIG. 4.—Face- and Root-Bend Specimens.

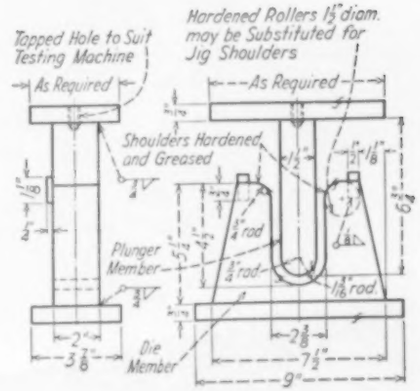


FIG. 5.—Guided-Bend Test Jig.

(*e*) The convex surface of each specimen shall be examined for the appearance of cracks or other open defects. The specimen shall be considered as having failed if a crack or other open defect, exceeding $\frac{1}{8}$ in. measured in any direction, is present after the bending. Cracks occurring on the corners of the specimen during testing shall not be considered.

(*f*) Welding rods of all classifications, except GB45, shall be capable of producing satisfactory welds which will conform to the face- and root-bend test requirements prescribed in Paragraphs (*a*) to (*e*) above, for all positions of welding.

Permissible Variations in Dimensions

7. The diameter of the rod shall not vary more than plus or minus 0.005 in. from the standard size specified. Cut lengths shall not vary from that specified by more than plus 0 or minus $\frac{1}{4}$ in.

Workmanship and Finish

8. (*a*) Rods shall be of uniform quality and free from injurious segregation, oxides, pipe, seams, or other irregularities.

(*b*) Rods shall be cold-drawn to a smooth finish, free from slivers, depressions, scratches, scale, lime, or foreign matter other than oil, except that rods may have a copper coating.

(*c*) The rods shall be carefully oiled with the minimum amount necessary to prevent rusting, except when copper-coated or otherwise treated to prevent rusting.

Packing

9. The rods shall be suitably packed, wrapped, boxed, or crated to protect against injury during shipment or under normal dry storage conditions, as follows:

(*a*) Bundles of 50 or 100 lb. net weight,

(*b*) Boxes or kegs of 50, 100, or 300 lb. net weight.

Marking

10. (*a*) Welding rods $\frac{1}{8}$ in. and over in diameter shall be marked or stamped with positive identification marks at intervals of not more than 18 in. Such marks shall be clearly distinguishable and shall identify the trade designation of the manufacturer or the classification number of the welding rod.

(*b*) All bundles, boxes, or kegs shall be legibly marked with the following information:

(*1*) Classification,

(*2*) Manufacturer's name and trade designation, and

(*3*) Standard size and length.

Guarantee

11. The manufacturer shall make tests at frequent intervals in accordance with the methods prescribed in these specifications, and shall guarantee that the rods in all sizes and classes conform to these specifications, and the marking of the classification number on the container shall be indication of this fact. The manufacturer's responsibility shall be limited to replacement of any rods which do not conform to the requirements of these specifications.

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(*Continued on page 624*)

Design of Welded Steelwork in Bridgewater Bridge, Tasmania*

By David Victor Isaacs†

Summary

The paper discusses details of the welded design of the new Bridgewater Bridge, Tasmania. Attention is confined mainly to the development of new types of connections and make-ups of members for the design of the 157 ft. 6 in. trusses forming part of the bridge. Particular attention is paid to the inportance of fatigue as affecting welded design.

Introduction

BRIDGEWATER Bridge is a combined road and rail structure crossing the estuary of the River Derwent twelve miles upstream from Hobart. It is being built to replace two existing old structures, one a road bridge and one a rail bridge, and must allow the passage of river traffic to and from the upper reaches of the river.

The existing structures are both mainly of timber, founded on piles, and include old iron swing spans which provide far too small a passage-way for the ocean-going boats shortly expected. The new structure is 1109 ft. long (center to center of end bearings), consisting mainly of welded 57 ft. 6 in. plate girder spans carried on concrete piers, which are in turn carried by long composite timber and reinforced concrete piles; but over the deepest part of the river the plate girder spans give way to three welded truss spans, including a lift span giving a clearance of 98 ft. 6 in. above high water. These three spans are carried on concrete caissons carried to bedrock, and the design of these spans is sufficiently unusual to warrant special description.

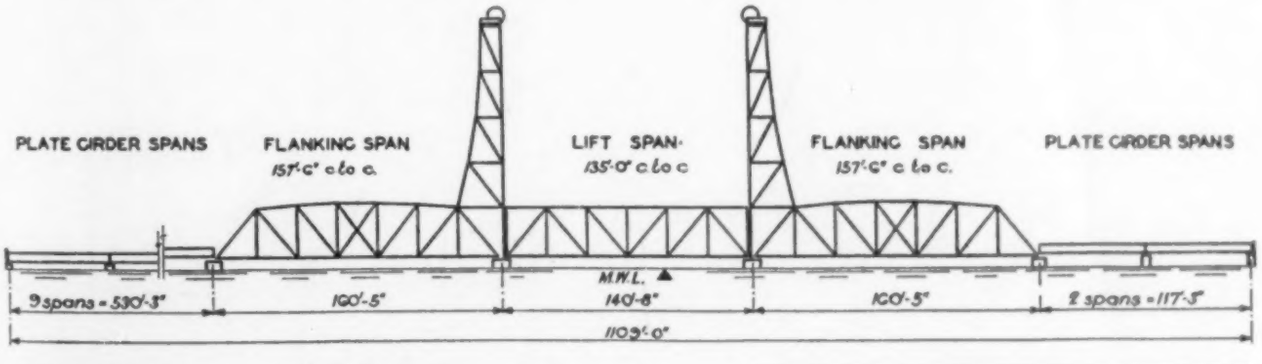
In 1935, the author was commissioned by the Tasmanian Department of Public Works to act as Consultant to the Department and advise on the type of structure most suitable for electric welding in a bridge of the type now being built. In view of the fact that previous Departmental experience with welding had been very favorable, the Department was anxious to adopt welded construction throughout; but it was disturbed by knowledge of the shortcomings of much welded work in fatigue conditions such as those imposed by the railway loading, and by responsible overseas condemnation of welding for railway truss work.

The author, after investigating in collaboration with the Department several different possibilities in construction, developed a new type of make-up for members and of joint detailing which put the ordinary Pratt type truss in the best position for cost for the truss portion, and so alleviated the fatigue problem as to allow economical design of joints. The anticipated construction of the bridge did not go ahead as soon as was expected, otherwise this paper might have been written some three or four years ago.

The Pratt truss spans are one of 135 ft. used as a lift span over the navigation channel, and two flanking spans of 157 ft. 6 in., each of which carries a lift span tower at one end. (See Fig. 1.) The cross section of the bridge on the truss portion is shown in Fig. 2. The use of the

* Reprinted from *Journal of the Institution of Engineers Australia*, December, 1941.

† This paper, No. 746, originated in the Melbourne Division of The Institution. The author is a Consulting Engineer of Melbourne.



RAILWAY LOADING — COOPER'S E.30

3-LANE ROADWAY LOADING — STANDARD TASMANIAN HIGHWAY LOADINGS
1-CRUSHER LANE
2-TRUCK LANES
See table opposite for equivalent loadings

Span (Ft.)	Equivalent loads per sq. ft.	
	10' Crusher Lane	10' Truck Lane
60	152 lb/ft'	66 lb/ft'
90	124	55
120	118	55
160	99	55

Fig. 1—General Elevation and Details of Loading

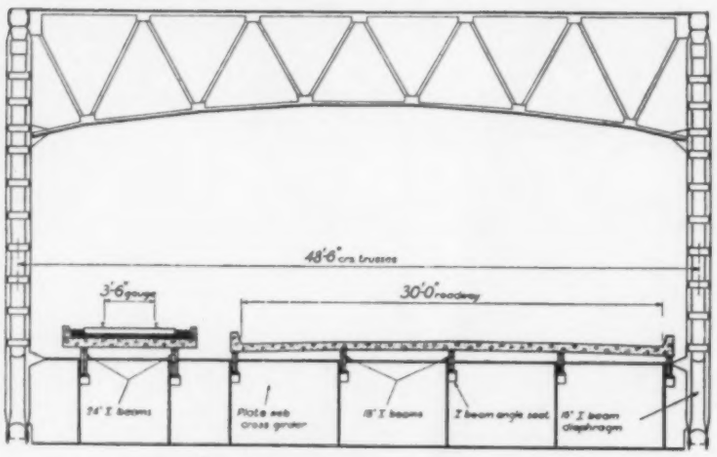


Fig. 2—Cross Section Through Center of 157 Ft. 6 In. Span

long-span cross girders shown in Fig. 2 is justified by foundation and truss economies, certainty of load distribution to the trusses, and appearance. In the plate girder approach spans and the flanking truss spans, concrete decks are used for both the road and ballasted railway track, but in the lift span timber decks are used for lightness.

Welding Considerations

The author, as early as 1931, had carried out research work on the distribution of stresses across and along fillet welds,* and even though allowance was made in this for plastic adjustment of weld and parent metal, the margin between fatigue strength and static strength was too great to give hope of a really sound and economical job based on the use of fillet welds for main stress transfer. This viewpoint was entirely supported by overseas fatigue tests on fillet welds then coming to hand (in 1935). There seemed every reason, however, for allowing the use of fairly high working stresses in butt welds, especially where these were to be flush-ground, and located in thick metal where accurate alignment of the metal was possible on opposite sides of the weld.† Having in mind, therefore, a type of structure in which butt welds would be used for all major connections, the author decided on a working stress in flush-ground butt welds or slot welds, in tension or compression, of 15,680 psi. This value was chosen after consideration of first class field welding conditions (which would apply to the whole work), and also the general degree of load fluctuation to be expected. Wherever any special conditions, such as inability to effect flush grinding or expected difficulties of fabrication were to be met, the use of lower stresses was intended. The general background created by adoption of this basic stress of 15,680 psi. was then kept in mind in planning the general structure.

Equally as important as the selection of the proper type of major weld, with its working stress, was the selection of a system of make-ups for members which would permit a minimum number of welds between the components of these members, and a convenient number of large rolled sections. By using a suitable association of stiff rolled sections, and relatively flexible plates, the problem of maintaining completed members free from distortion would be largely solved, while at the same time the process of tacking together and actual welding would be promoted. Field erection would in any case be largely governed by the choice of make-ups for the various members, but a proper choice of these would greatly facilitate the erection, and indirectly improve the quality of the associated welding.

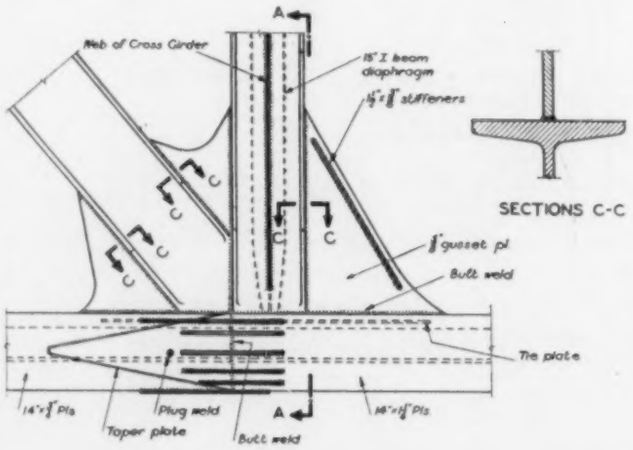
A further principle of prime importance was that all stress transfers from member to member should be made through as direct a path as possible, with smooth and gradual changes of direction in all lines of principal stress.

"Force Flow" Design

Thoughts on the above lines led the author to a new conception of welded truss design which seemed best described by the term "force flow." The underlying principle is well illustrated by reference to Fig. 3, which shows details of the lower chord joint L_2 of one of the 157 ft. 6 in. railway side trusses.

Vertical and diagonal members meeting at this joint each consist of two I-beams without cover plates, the webs of the I-beams being centered in two respective planes which are also the planes of the centers of the added shaped gusset plates. Gussets and I-beams are butt welded together. The web thickness of the 13-in. I-beams of the vertical is 0.35 in., that of the 16-in. I-beams of the diagonal 0.40 in., and the gusset plates are $^3/_8$ in. thick. Forces passing from gusset to I-beam thus do so without any marked change in stress intensity. Forces pass in this manner from the flanges of the I-

* See *Jour. Inst. Engineers Australia*, 8 (8), 286 (Aug. 1936).
† Compare S.A.A. Code No. C.A. 8-1939, clause 16.



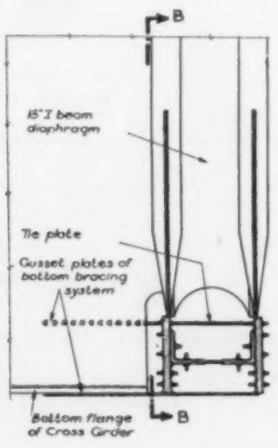


Fig. 3—L_2 Joint—157 Ft. 6 In. Railway Side Truss. Section *BB* Left; Section *AA* Right

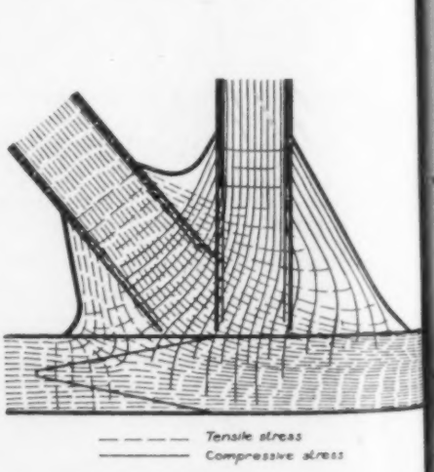


Fig. 4—Presumptive Lines of Force Flow, L_2 Joint

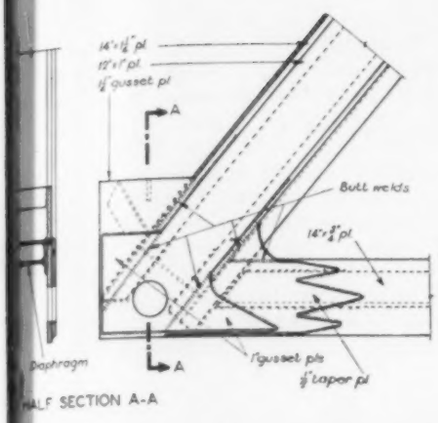


Fig. 5—L_0 Joint, 157 Ft. 6 In. Railway Side Truss

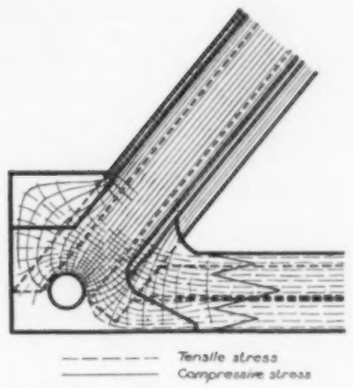


Fig. 6—Presumptive Lines of Force Flow, L_0 Joint

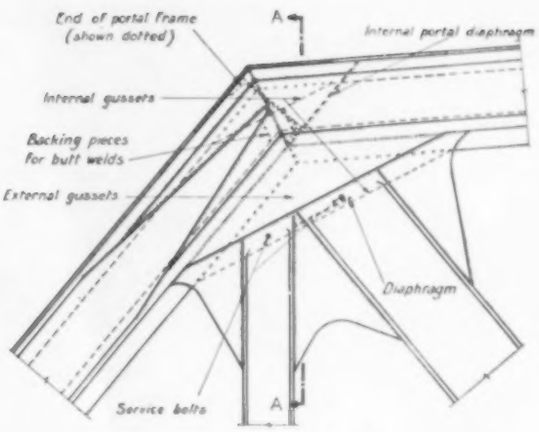


Fig. 7—U_1 Joint, 157 Ft. 6 In. Railway Side Truss

beams into the gussets; and to assist in a smooth force transference, the flanges of the I-beams are tapered off by oxy-cutting, so that little outstanding metal remains near the end of the member. The body of metal formed by the lower end of vertical and diagonal members with the shaped gusset plates, connects directly to the top of the lower chord, into which the horizontal force increment of the panel point thus flows directly; the tapered cover plates added to the sides of the lower chord facilitate smooth distribution of this force increment. The general mechanism of force transfer is illustrated diagrammatically in Fig. 4.

In this joint all the welds are readily made as a species of butt weld—the necessary vee-ing is not troublesome as the gussets must be oxy-cut in any case—and the direct stresses are sufficiently low to allow the elimination of flush grinding.

A greater use of conventional butt welds is made in the case of other joints, e.g., joint L_0, which is illustrated for a railway side truss in Figs. 5 and 6. In this case the welds are flush-ground, because of the stresses involved, and some perform the double function of slot welds and butt welds.

Figure 7 shows joints U_1 of a railway side 157 ft. 6 in. truss, and it will be seen that the general principles follow on the lines already discussed. The provision of service holes for erection of members should be noted.

Stresses Used in Truss Joints

It should be clear that no simple theoretical method of analysis could hope to deal accurately with the internal stress conditions developed in any of the joints discussed above. Only smugness resulting from frequent repetition of an empirical process lulls the average designer into believing that gusset-plated joints in riveted work are theoretically simple. A judicious admixture of theoretical background and an innate sense of fitness seemed therefore the best general formula for design of the various truss joints.

On this basis, therefore, a more or less empirical design framework was developed. Taking Fig. 8 as representing most typical welds, this framework was as follows:

(*a*) Uniform or "straight line" stress distributions to be assumed throughout.

(*b*) Each joint to be examined for stress along several lines, and for bending across critical sections.

(*c*) The complete flange load of any I-beam to be assumed transferred by welds L, assumed to act purely in shear, at stresses not in excess of 11,200 psi.

(*d*) Half the full load of any I-beam to be assumed—quite arbitrarily—to be transferred by a direct or principal stress at a value not in excess of 14,000 psi. on welds M.

(*e*) The angles A to be arbitrarily not more than 30°, and not less than 20°, and all curves swept in at radii suitable on inspection.

(*f*) The maximum principal stress on welds N (obtained by combining shear and bending stresses) to be not more than 12,320 psi.—a stress allowing for certain small eccentricities inherent in this type of joint.

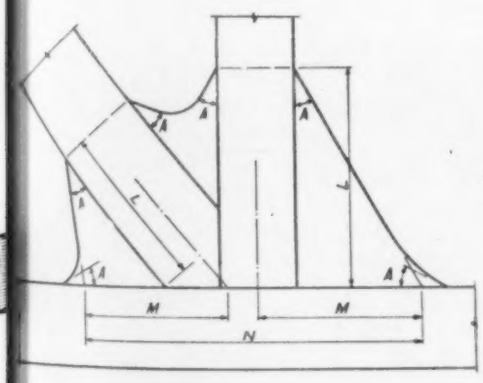


Fig. 8—Controlling Dimensions, L_2 Joint

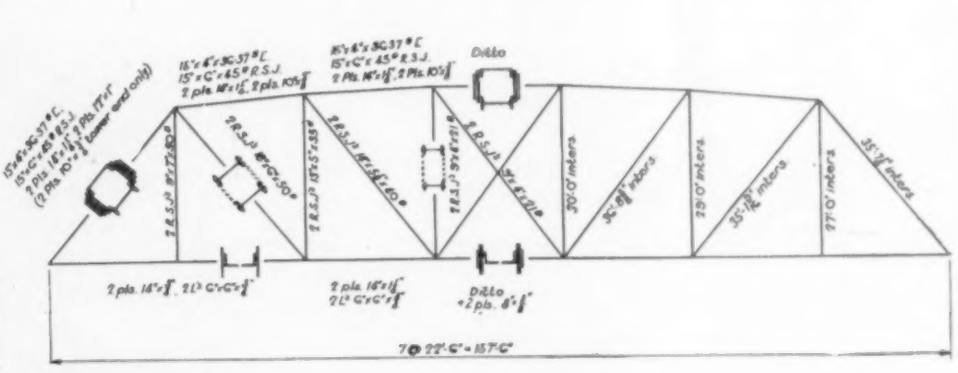


Fig. 9—General Make-Ups and Lengths of Members in 157 Ft. 6 In. Railway Side Truss

The general soundness of the above framework was borne out in actual design by the fact that, while (*c*), (*d*), (*e*) and (*f*) were independently formulated, their operation proved to be mutually complementary and consistent.

The L_0 and U_1 joints differ from the typical joints of Fig. 8, so further considerations applied.

In the case of the L_0 joints, butt welds of conventional form were used, either flush-ground both sides, or flush-ground one side and made against a backing piece, or similar metal, on the other. The aim was to limit the direct stress perpendicular to the axis of the weld to not more than 15,680 psi., and the general design of the L_0 joints was therefore based, in the first instance, on parent metal stresses. Such parent metal stresses, near ends of gusset plates, would actually be lower than those calculated on an assumption of "straight line" stress distribution, and in most other regions would actually be higher than those calculated on this assumption. The following were therefore added to the framework:

(*g*) Rules (*a*) and (*b*), as above, to be applied to determine stresses in parent metal at joint L_0.

(*h*) At points near ends of gusset plates, tensile stress to be limited to an apparent value of 19,040 psi.

(*i*) At all other points tensile stresses to be limited to an apparent value of 15,680 psi., and compressive stresses to an apparent value of 12,320 psi.

(*j*) At points close to butt welds or slot welds, no stresses to exceed $^7/_8$ths of the values applicable to parent metal.

In the case of the U_1 (or hip) joints, the controlling conditions embraced most of those considered in relation to Fig. 8 and also Joints L_0. The rules for design thus became:

(*k*) Rules (*a*) and (*b*) as above to be applied to determine stresses in welds and parent metal at joints U_1.

(*l*) Rules (*c*) to (*f*) to be applied in relation to hip vertical and diagonal.

(*m*) Rules (*h*) to (*j*) to be applied in relation to the joint as a whole.

Stresses Used in Fillet Welds

Fillet welds would necessarily be used in the bridge structure in positions of minor importance or minimum fatigue, where in any case ample margins of strength could be obtained at little cost. The author's investigations into fillet welds* served as a basis on which to fix working stresses for such welds, and a scheme was drawn up, separating loadings in two types (dependent on fatigue conditions), and welds into three types (according to the positions of adjacent parent metal and directions of the lines of force).

The two types of loading were nominally:

Rail Type Loading:

Loadings in—
Rail stringers and supports.
Rail half of cross girders.
Rail trusses (minor details).

Road Type Loading:

Loadings in—
Road stringers and supports.
Road half of cross girders.
Road trusses (minor details).
Wind and sway bracing, etc.

The three types of welds were then set out as.

Type A Welds:

(*a*) Rail or Road types of loading in the following positions:
Stringers (and supports and connections).
Stiffeners.
Plate girders.

(*b*) Road types of loading in the following positions:
End connections of floorbeams.
Minor truss details.

Type B Welds:

(*a*) Rail types of loading in the following positions:
End connections of floorbeams.
Minor truss details.

(*b*) Road types of loading in the following positions:
Connections where two or more parallel plates (even though included above) are connected by welds close to, or at the edge of *each* plate.

Type C Welds:

Rail types of loading in positions as described in (*b*) of Type B welds.

The allowable fatigue working stress in any fillet weld on this basis was then the static strength multiplied by a factor as tabulated in Table 1.

Table 1—Fatigue Factors in Fillet Welds

M = maximum loading in weld. N = minimum loading in weld.

Ratio N/M	Fatigue Factor for Various Types of Weld		
	Type A	Type B	Type C
1.0	1.00	1.00	1.00
0.9	0.94	0.91	0.88
0.8	0.88	0.83	0.79
0.7	0.83	0.77	0.71
0.6	0.79	0.71	0.65
0.5	0.75	0.67	0.60
0.4	0.71	0.62	0.56
0.3	0.68	0.59	0.52
0.2	0.65	0.56	0.48
0.1	0.62	0.53	0.45
0.0	0.60	0.50	0.43
−0.1	0.58	0.47	0.40
−0.2	0.56	0.45	0.38
−0.3	0.54	0.43	0.37
−0.4	0.52	0.41	0.35
−0.5	0.50	0.40	0.33

Static strengths of fillet welds were taken according to the then current S.A.A. code, now superseded.

Design of Taper Plates and Adjacent Welds

Taper plates are used in all chords, where force increments necessitate an increase of sectional area. Theoretically such plates should carry almost uniform stress throughout, by virtue of their taper. They introduce distribution stresses, however, into the main chord section to which they are added, and as a matter of policy, were therefore given a taper extending over a length equal to twice their maximum width. With these proportions the disturbance to even stress conditions across the main chord section was regarded as being of no practical account. The thickening of chord metal consequent on the addition of a taper plate involves a lateral displacement of the plane of force action, in the metal

*. Ibid.

thickened. This displacement is effected gradually over the length of the taper plate, provided the chord has adjacent tie plates or cross webs, a condition fulfilled in all cases.

The addition of gusset plates to the edge of any chord necessarily tends to increase the chord stress on the edge of the chord remote from the gussets. The taper plates in all instances are therefore added somewhat toward that end of the truss joint where the chord force is lower; and their average stress at the wide end of the taper is therefore under the full parent metal stress of 17,920 psi.

The welds connecting the taper plates to the main body of metal are inclined fillets. On the basis of weld loadings above, working loads were as set out in Table 2.

Table 2—Taper Plate Welds

Fillet Weld Size, (In.)	Safe Loading of Weld: Road Side Truss Lb. per Linear In.	Safe Loading of Weld: Railway Side Truss Lb. per Linear In.
1/4	1520	1250
5/16	1900	1570
3/8	2280	1880
1/2	3040	2510

At the end of member L_0L_1 where it merges into joint L_0 the rolled angle sections are discontinued, and their load transferred to taper plates. (See Fig. 5.) The loading on fillet welds used on the angles opposite these taper plates results from complete transfer of the load in the angles, and gives rise to pronounced fatigue effects. The loadings were set down as shown in Table 3.

Table 3—Side Fillet Weld Loads at L_0

Fillet Weld Size, In.	Safe Loading of Weld: Road Side Truss, Lb. per Linear In.	Safe Loading of Weld: Railway Side Truss, Lb. per Linear In.
5/16	1550	1250
3/8	1860	1770
1/2	2660	2020

Make-Ups of Members

The make-ups of the various members are shown in Fig. 9 for a railway side truss of 157 ft. 6 in. span. No member could be said to have a conventional cross section.

End post and top chord members could be designed as closed sections, even though the bridge is not far from the sea, because the whole internal space would be reputedly sealed (and there would therefore be extremely little if any change of air inside the members), and also because no metal would be thinner than 3/8 in. The use of a 15-in. I-beam and a 15-in. channel at bottom and top, respectively, of these members, with heavy plates on the sides, was regarded as being very suitable for welding, because the rolled sections would form a stiff welding "table" for attachment of the plates. Experience has shown that all that was hoped for in regard to ease of welding and freedom from distortion has been realized. Efficiency of cross section was also achieved by the omission of all tie plates and lacing, with their welds, and by virtue of the relatively large radius of gyration accompanying the closed sections. This is illustrated in Table 4 by the tabulation of maximum values of l/r and minimum column working stresses.*

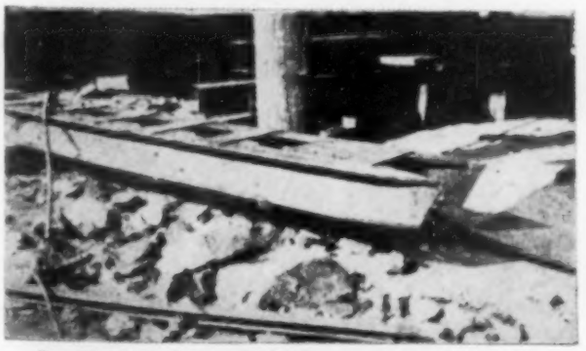


Fig. 10—End of Truss Web Member During Fabrication

Fig. 11—Hip Joint, Railway Truss, Tower End. U_1L_0 Lies to the Right

Table 4—Least Favorable Column Conditions in Top Chords and End Posts

Member	Maximum l/r	Minimum Column Working Stress, Psi.*
Railway end posts	87.2	11,070
Roadway end posts	83.6	11,310
Railway top chords	53.3	13,740
Roadway top chords	49.4	14,040

These high allowable working stresses (compared with 15,000 psi., the maximum possible) were attained without using unduly wide members subject to high secondary stress. The wide range of cross-sectional areas used is set out in Table 5.

Table 5—Maximum and Minimum Top Chord and End Post Cross Sections

Member	Make-Up	Area, Sq. In.
Railway end post, tower end, 157 ft. 6 in. span	15 in. x 4 in. x 36.37 lb. channel	10.70
	15 in. x 6 in. x 45 lb. I-beam	13.24
	2-pls. 14 in. x 1 1/4 in.	35.00
	2-pls. 12 in. x 1 in.	24.00
	2-pls. 10 in. x 3/4 in.	15.00
		97.94
Roadway top chord, 135 ft. 0 in. span	15 in. x 4 in. x 36.37 lb. channel	10.70
	15 in. x 6 in. x 45 lb. I-beam	13.24
	2-pls. 14 in. x 3/8 in.	10.50
		34.44

Lower chord members consisted in all cases of side plates and two rolled angles with associated butt-welded tie plates, as shown in Fig. 9. Though some care had to be taken to prevent the cross section from warping from its true form, the general section, as anticipated, remained free from distortion in all cases; when it was laid

* Column working stresses for chords were calculated as:
Allowable column stress = $8.03 - 0.0357\ l/r$ tons per sq. in.
= $18{,}000 - 80\ l/r$ psi.

Fig. 12—157 Ft. 6 In. Trusses During Erection

out and welded as a continuous bottom chord stretching from end to end of the truss, the whole was so true that errors shown by theodolite were negligible. Advantages leading to the adoption of this type of member were extreme openness of the cross section for butt welding of main splices, a minimum of welding and components, a minimum of interference with uniform stress conditions by tie plates, a maximum of useful metal (mainly concentrated under main gusset plates at truss joints), and a wide possible variation of sectional area with approximately constant overall sizes. The last advantage is illustrated by the details shown in Table 6.

Table 6—Maximum and Minimum Bottom Chord Cross Sections

Member	Make-Up	Area, Sq. In.
Railway truss, center panel, 157 ft. 6 in. span	2-angles 6 in. x 6 in. x $^3/_4$ in.	16.88
	2-pls. 14 in. x $1^1/_4$ in.	35.00
	2-pls. 8 in. x $^3/_8$ in.	6.00
		57.88
Roadway truss, end panels, 135 ft. 0 in. span	2-angles 5 in. x 3 in. x $^3/_8$ in.	5.72
	2-pls. 14 in. x $^1/_2$ in.	14.00
		19.72

Web members generally each consisted of two I-beams tie plated together so that their webs were parallel and a clear 15 in. apart. Welding for such a cross section was very easy, being confined merely to attachment of the tie plates (concerning which some discussion will follow later in this paper). Since each I-beam in any web member was centered exactly in the plane of the welds transferring its load at truss joints, all this load was automatically centered axially on the I-beam without the necessity for end tie plates, as usually found in truss work. Such end tie plates can never be 100% efficient so that there was some advantage in being able to remove the necessity for them. The use of double I-beams resulted in members whose least radius of gyration was always the major radius of gyration for a single I-beam of the size used. Ratios of l/r were thus low in all web members taking compression, and efficient members thus resulted. This is illustrated in Table 7.

Some idea of the variation in cross section of web members is given in Table 8.

Table 7—Column Conditions for Truss Verticals of 157 Ft. 6 In. Truss

	Railway Side Truss		Roadway Side Truss	
Member	l/r	Allowable Column Working Stress, Psi.	l/r	Allowable Column Working Stress, Psi.
U_2L_2	66.3	13,680	85.3	11,180
U_3L_3	99.4	10,040	99.4	10,040

Table 8—Maximum and Minimum Web Member Cross Sections 157 Ft. 6 In. Trusses

Member	Make-Up	Area, Sq. In.
Railway truss, U_1L_2	2 I-beams 16 in. x 6 in. x 50 lb.	29.41
Railway and roadway trusses, minimum section, in several members	2 I-beams 9 in. x 4 in. x 21 lb.	12.45

Tension Splices in Lower Chords

With the lower chord section open for flush-ground butt welds, there was no reason why splices in this member should not be made wherever required to suit lengths of material and handling of unit lengths of chord. For this reason some splices were made right through the cross section of the chord at one point. Such a splice was made at the center of the center panel L_3L_4 of the 157 ft. 6 in. railway side truss. (Figure 3 shows a similar splice at L_2.) The components of the chord at this point are thick, and presented no difficulty in aligning opposite halves of the splice, so a working stress of 15,680 psi. was used in the flush-ground double V butt welds. Area was added to the chord near the splice by the addition of tapered 1 in. x $^3/_8$-in. flats on edge, and some illustrative figures for these are set out in Table 9.

Table 9—Central Splice of L_3 L_4, 157 Ft. 6 In. Railway Truss

Area of chord, as previously tabulated, carrying 17,920 psi. tension	= 57.88 sq. in.
Area of 22 flats on edge 1 in. x $^3/_8$ in.	= 8.25 sq. in.
Area of metal at splice	= 66.13 sq. in.
Average stress at splice neglecting central tie plate	= 15,680 psi.

The flats on edge are evenly distributed round the metal spliced, so each takes the same load, and the calculated stress of 15,680 psi. on the center of the splice may therefore be regarded as close to the true value. Stresses in the fillet welds joining the flats to the main section are very low, being nominally only 340 lb. per linear inch on the $^1/_4$-in. fillets.

Floor Systems

The deck of the flanking spans, for both railway and roadway sections, is of reinforced concrete slabs supported on I-beam stringers. (See Fig. 2.) For the lift span, timber decking is used in lieu of concrete for lightness.

Calculations showed that a continuous concrete deck of the full length of the flanking spans would not introduce excessive secondary stresses in floorbeams or truss verticals, provided the deck was cast in a manner practically eliminating such secondary stresses as far as they were due to dead load. The deck was accordingly cast in sections to achieve this necessary result.

Owing to the relative deflections of floorbeams when

supporting heavily loaded stringers it was not thought worth while to make stringers continuous across floorbeams. The type of stringer to floorbeam connection devised to give a flexible connection at this point utilizes an end stiffener in direct bearing on a shelf angle.

Floorbeams are welded plate girders of conventional design, having a span : depth ratio of 8.0.

Bracing Systems

Upper and lower bracing systems, together with the portal bracing, were of conventional type. Owing to the width of the bridge in relation to the panel length, *K*-bracing was used; and the fact that this type of bracing is accompanied by low secondary stresses was regarded as useful in relation to the general rigidity of a welded bridge.

At the portal frames, internal diaphragms within the chords at the hip joint enabled a very efficient portal-to-truss connection to be made. (See Fig. 7.)

Braking struts are used under railway stringers and frame into a sub-system of the general lower bracing system.

In the case of the lift span, diagonal braces radiate from near the centers of the lower flanges of floorbeams, to the approximate third points of the upper flanges, thus staying the latter against buckling, by direct connection to the bottom bracing system.

Tie-Plated Column Members of Trusses

The only column members of the trusses which have not solid webs for all possible shears are the main verticals and diagonals; these are made up, in each instance, of two I-beams with webs parallel and fairly well separated. The radius of gyration calculated for bending perpendicular to the webs of the I-beams is somewhat greater than that for bending parallel to the webs. With this as one of the governing conditions, a decision had to be made between lacing and tie plates to hold the I-beams together.

Factors governing the use of tie plates were held to be:

(*a*) Ease of welding and general fabrication.
(*b*) Greater lateral flexibility of the main members, resulting in slightly lower secondary stresses in the bridge as a whole (as discussed later).
(*c*) Lower secondary stress within the member (i.e., lower secondary stresses, due to interaction of tie plates and main components of members only in a tie-plated make-up, than due to interaction of lacing, end die plates, and main components of members in a laced make-up).

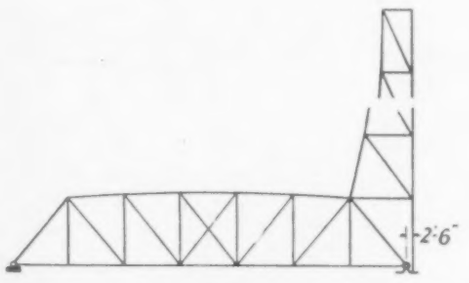


Fig. 13—Elevation Showing Bearing Arrangements of 157 Ft. 6 In. Spans and Towers

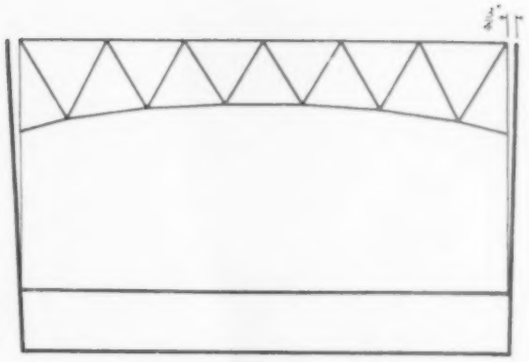


Fig. 14—Cross Sections Showing Method of Welding Floor Beams to Truss Verticals to Reduce Secondary Stresses

As against these, tie plates involve large local bending stresses in the main components of members, whenever the shear force on the member is not low.

Tie plates were actually adopted, leaving the question of suitable column working stresses somewhat doubtful. In the absence of any specific information, the author determined on the following working stresses.

(*a*) For primary failure as a long column,
$f_a = 8.03 - 0.0357\ l/r$ tons per sq. in. (18,000 $- 80\ l/r$ lb. per sq. in.).

(*b*) For secondary failure due to the simultaneous action of direct column loads, and local bending due to tie plate action under a column shear to $2^1/_2\%$ of the column load,
$f_a = 9.37 - 0.0447\ l/r$ tons per sq. in. (21,000 $- 100\ l/r$ lb. per sq. in.),
this stress to be checked for the oblique axis readily determined from calculation based on properties for the *xx* and *yy* axes) about which failure due to combined bending and direct stress is most likely.

(*c*) For local bending due to tie plate action alone, with $2^1/_2\%$ of the direct column load taken in shear by tie plate action,
f_b not more than $0.35\ f_a$.

(*d*) For bending stress in the tie plates, under $2^1/_2\%$ shear as referred to above,
$f_t = 8.03 - 0.0937\ d/t$ tons per sq. in. (18,000 $- 210\ d/t$ lb. per sq. in.).
where d = distance between center of gravity lines of sections joined.
t = thickness of tie plate.

These results served to secure economical use of column material for direct stress, at the same time as they indirectly served to limit spacings of tie plates to values producing only moderate column bending stresses under $2^1/_2\%$ shear.

Secondary Stresses

The general rigidity of welded joints tends to give rise to secondary stresses greater than would occur with riveted joints.

Secondary stresses in a structure of the type under discussion are mainly of moment in the following:

(*a*) Trusses as a whole.
(*b*) Cross girders with verticals and sway bracing.
(*c*) Wind bracing and lateral bracing generally.
(*d*) Interrelation of truss and floor systems.

No unusual features were apparent in regard to the trusses as a whole, except that a convenient detail had to

be devised for linking the lift span tower to one end of each flanking span truss. The detail adopted has the advantage of being simple from the point of view of fabrication, and of a form not involving excessive secondary stress. Figure 13 shows that, in this detail, the bottom ends of the front tower legs—each carrying approximately one-quarter of the dead load of the lift span, and an equal loading from the counterweights—rest directly on the substructure. The end of the flanking span truss is centered 2 ft. 6 in. away on a pin-jointed bearing. Secondary stresses in the truss near its bearing are thus kept low, by keeping the truss separate from the bottom of the stiff tower leg; and secondary stresses in the bottom of the tower leg, as caused by deflection in the truss, are kept as low as possible by leaving this tower leg free to deflect from the vertical as a simple cantilever to the level of the top of the truss.

Secondary stresses in the lower chords under the hip verticals were kept low by using low working stresses in the hip verticals.

The problem of easing secondary stresses under floorbeam deflections was accentuated by the relative width of the bridge as compared with the depths of trusses, and the relative shallowness of the floorbeams. Two palliatives were therefore included in the solution, viz., the adoption of laterally flexible truss verticals (utilizing tie plates in lieu of lacing) and fabrication of the work in a way to give no end fixing moments in floorbeams, while the trusses are fully loaded. The details of fabrication therefore required truss verticals to be welded to floorbeams with an outward cant, as illustrated in Fig. 14. Trusses were therefore actually welded to floorbeams while lying out of a vertical plane, then drawn in about $1^1/_2$ in. at the top in pairs while being welded to the sway bracing, and then finally the portal frames were welded into position. Under full floorbeam loads, this solution does not provide full compensation; but if one floorbeam is fully loaded, others will be only partly loaded, so that the compromise is actually a very fair one.

Wind bracing and lateral bracing generally being of the *K* type, secondary stresses due to changes of length in the main truss chords are very low.

In bridges carrying rigid decks without expansion joints, secondary stresses occur in the form of lateral bending of floorbeams (and, in the present instance, of truss verticals also). This aspect has already been referred to in connection with discussion of the floor system, and the pronouncement made that no excessive secondary stresses were expected if the deck concrete were cast so as to eliminate dead load from the loads causing secondary stress. The truth of this pronouncement may be generally gaged from the following considerations.

(*a*) The deck, by being elevated some 6 ft. above the lower chord, lies at a level where 17,920 psi. in the lower chord would be equivalent in effect to only 11,200 psi. applied as an extending stress in steel at deck level.

(*b*) Dead load stresses in the case of the roadside truss amount to approximately 62% of the total chord stresses, and in the case of the railside truss, to approximately 42%.

(*c*) The end floorbeams do not frame into any truss members and are therefore relatively free to move under longitudinal deck movements.

(*d*) The hip vertical in all cases is designed for a working stress not in excess of 8960 psi., and has therefore ample margin to accommodate bending stresses introduced by longitudinal deck movements transmitted via floorbeams.

(*e*) Some flexibility exists between the points where stringers frame into floorbeams, and where the floorbeams frame into truss members.

Towers for Lift Span

The towers for the lift span are subjected to three main forms of primary loading, viz., vertical loads comprising dead loads of lift span and counterweights (with a certain amount of impact during operation), vertical loads comprising dead loads of towers, wheels, etc., and horizontal loads due to wind. No special efforts were therefore made to secure refinements of fabrication to reduce fatigue effects.

Front tower legs are of closed cross section, including as main metal two parallel I-beams, with two parallel plates on their flanges, while bracing members are in all cases two parallel tie-plated channels. Maximum and minimum make-ups are set out in Table 10.

Table 10—Maximum and Minimum Make-Ups of Tower Members

Member	Make-Up	Area, sq. in.
Front leg below portal	2 I-beams 18 in. x 6 in. x 55 lb.	32.36
	2 pls. 18 in. x $1^1/_4$ in.	45.00
		77.36
Front leg above portal	2 I-beams 18 in. x 6 in. x 55 lb.	32.36
	2 pls. 18 in. x $^3/_8$ in.	13.50
		45.86
Rear leg	2 channels 10 in. x $3^1/_2$ in. x 24.46 lb.	14.38
Bracing	2 channels 6 in. x 3 in. x 12.41 lb.	7.30

The front legs being subjected to considerable torsion, due to eccentrically located forces taken by the guides for the lift span, the solid webbed make-up is very efficient. For all possible positions of the lift span, horizontal forces thrown by it into the tower legs are thus resisted directly by a tower member strong enough to resist shear, torsion and bending moments.

Tie plates on the tie-plated bracing members were designed and spaced so as to produce working stresses not greater than those already given in the section of this paper dealing with tie-plated columns.

Acknowledgments

The author was engaged by the Tasmanian Department of Public Works as a Consultant, and wishes to record his acknowledgments to Mr. G. D. Balsille, M.I.E. Aust., Director of Public Works, and Mr. A. W. Knight, B.Sc., M.E., A.M.I.E.Aust., Chief Engineer of the same department, in connection with the publication of this paper.

Jigs for Flame Cutting Curved Surfaces

By C. N. Holwill* and A. N. Kugler†

AN INTERESTING adaptation of oxyacetylene machine flame cutting on cylindrical surfaces is shown in the fabrication of sugar crystallizers for the Olaa Sugar Plantation at Olaa, Hawaii. Several ingenious jigs and control devices were designed to facilitate rapid, accurate machine cutting of holes and slots in 3-in. and 16-in. pipe, after manual torch cutting had proved unsatisfactory.

Seven crystallizers were made, each consisting of a main column of 16-in. pipe, 19 ft. long, into which 148 holes were cut to receive branch pipes. The branch pipes were $7\frac{1}{2}$ ft. long, 3 in. diameter, and into each pipe were cut two wide slots measuring $13\frac{1}{2}$ by $3\frac{1}{4}$ in.

The first of the seven central columns had been perforated with a hand torch, requiring a day and a half to cut the 148 $3\frac{1}{2}$-in. holes. Because the finished cuts were rough, requiring considerable grinding before the branch pipes could be fitted in, it was deemed worth while to devise a special setup for machine gas cutting of the remaining six pipes. Accordingly a portable running table for a circle-cutting radiagraph machine was cut from $\frac{3}{16}$-in. plate and mounted on a cradle to fit the 16-in. pipe. Two chains with springs running beneath the pipe held the table securely. An elliptical cut in the center of the plate permitted the cutting of two holes at each position of the jig.

With this jig and a radiagraph the remaining shafts were cut in 5 to $5\frac{1}{2}$ hr. each, saving not only $6\frac{1}{2}$ hr. cutting time but also reducing oxygen consumption by half, as compared to the hand-cutting operation. Subsequent grinding was, of course, unnecessary. Oxygen consumption was 200 to 212 cu. ft. for each set of 148 holes, as compared to 400 cu. ft. when using the hand torch.

Even more ingenious were the jig and auxiliary devices constructed for cutting the slots in the smaller diameter pipe. As these slots were $3\frac{1}{4}$ in. wide, extending more than one-quarter of the way around the pipe circumference, the two end cuts were made by rotating the pipe beneath the torch. The side cuts, $13\frac{1}{2}$ in. long, were made with the radiagraph traveling on a track parallel to the pipe axis. As a study of the photographs shows, this jig was so made as to locate and cut the slots in exactly

* Manager, Hilo Branch, Hawaiian Gas Products, Ltd.
† Applied Eng. Dept., Air Reduction Sales Co., New York, N. Y.

Fig. 1

For cutting hundreds of holes in central columns of sugar crystallizers in Hawaii, this portable radiagraph table, clamped to the 16-in. pipe, permits cutting two holes at each position.

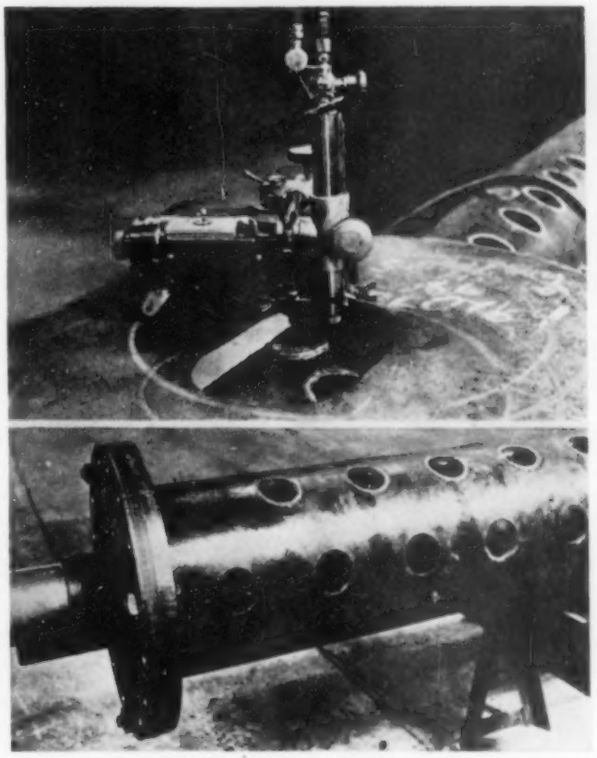


Fig. 2

A total of 148 holes were cut in each pipe in 5 to $5\frac{1}{2}$ hr., saving time and oxygen as compared with the first hand-cut holes. Flanges were also flame cut and double beveled on inside diameter for welding.

Fig. 3

Two slots were accurately cut in each of 518 branch pipes. Note fixed rod at left of radiagraph, for automatic stopping at end of cut. At right is the jig for positioning and rotating the pipe.

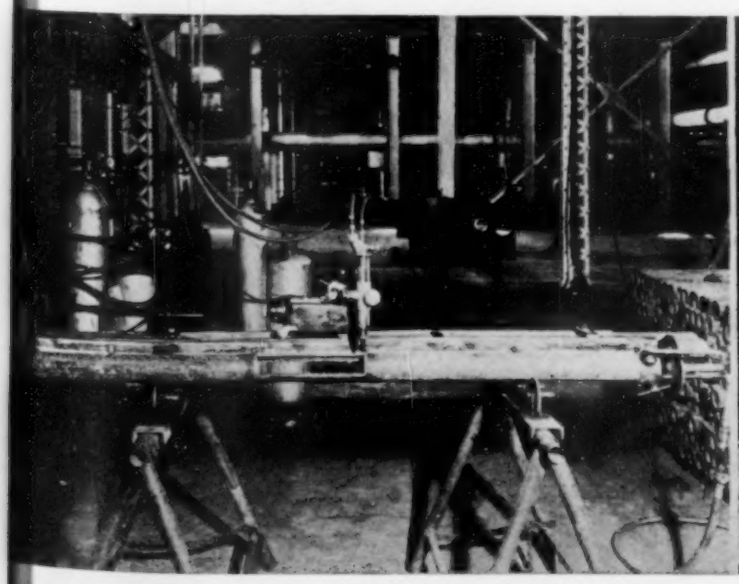
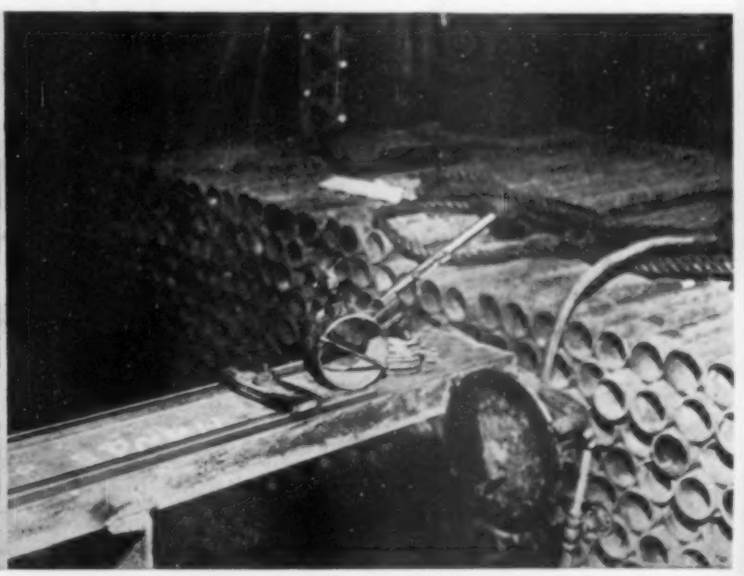


Fig. 4—Details of Jig

Disk has four stops for accurate positioning of side cuts of both slots. Crossbar on collar controls longitudinal position of slots, centering them at midsection of pipe.



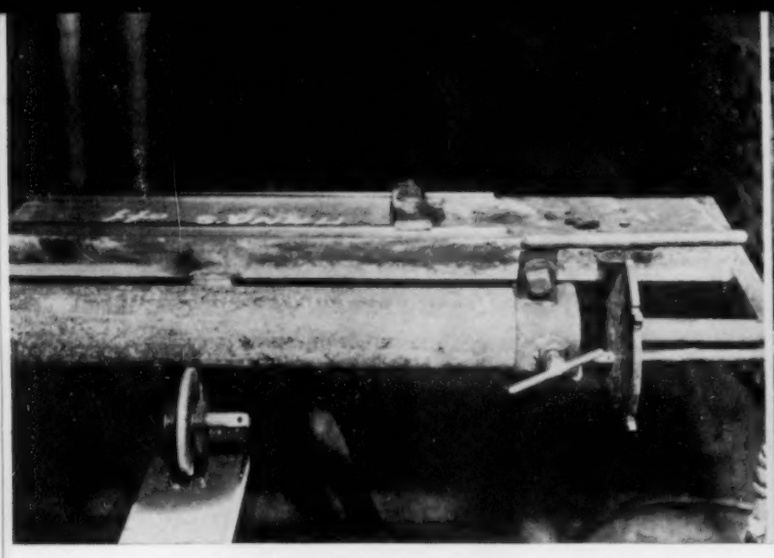


Fig. 5—Pipe Locked in Position for Slot Cutting
Hand lever on collar is also used to rotate the pipe slowly for cutting ends of slots.

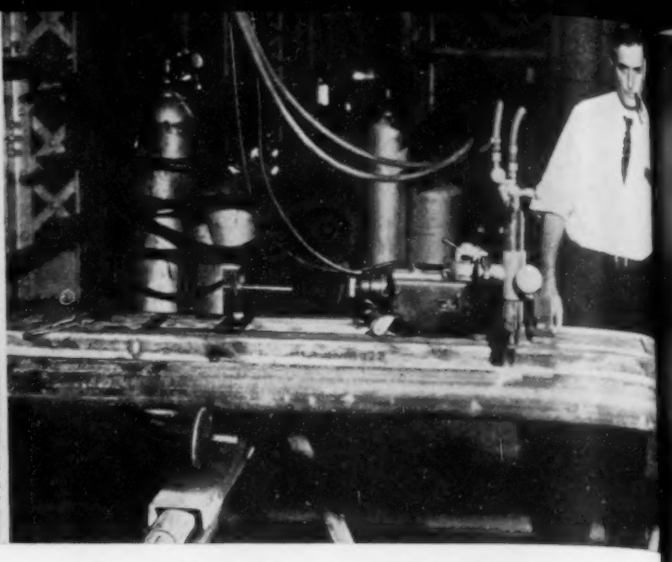


Fig. 6—Making the First Side Cut on 3-In. Extra Heavy Pipe
Both stopping devices are visible here. These, together with jig at end of pipe, eliminate necessity for scribing pipe to locate cutting positions.

the same position on each of the 518 pipes, without need for marking or scribing the pipes. A sleeve fitted and clamped to one end of the pipe governed its rotation by means of an adjustable arm which locked into various positions on a matched disk.

Starting at one corner the radiagraph cut one side of the slot, until stopped automatically by a fixed rod which threw a switch on the machine, disconnecting the main power supply. The operator then slowly rotated the pipe by means of the hand lever, to cut the slot end, and reversed the machine for the second side cut. At the end of this cut another fixed stop-bar threw the switch, and by manual rotation the slot cutting was completed. One purpose of the electrical stopping devices was to prevent wearing of the radiagraph drive wheel, such as would occur with mechanical stops. Four notches on the guide disk located the longitudinal cuts for two opposite slots.

While considerable time was spent in constructing the jig, this was more than justified in the speed and accuracy with which the cutting was done. A total of 1036 slots were cut at the midpoints of the branch pipes, which were then passed through opposite pairs of holes in the main columns and welded into place.

High-Pressure Piping

By H. J. Irrgang, Jr.

IN discussing the subject of high-pressure welding, an art which has more self-appointed experts, including myself, than probably any other mechanical art, and is, therefore, subject to wide differences of opinion, it is well to bear one important fundamental in mind as we go into the various phases of this art; namely, the human element. After the human element comes the next important step, establishing the proper procedure and welding technique, and seeing that it is followed.

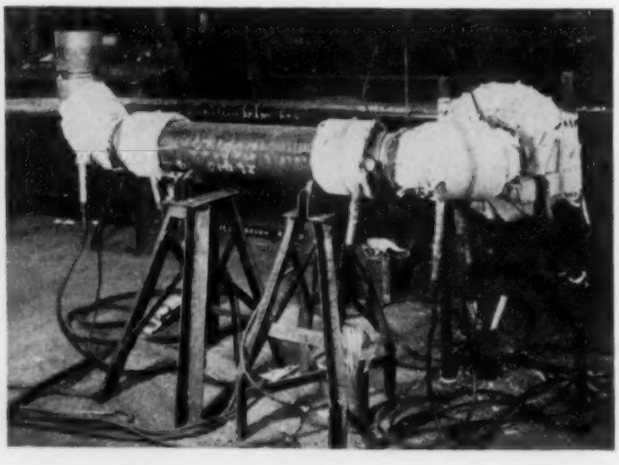


Fig. 1

It has been established that, if certain results are obtained by following a certain procedure, we are reasonably sure of attaining the same results every time this procedure is followed. With this in mind, I shall try to take you through the various stages which we follow in making a high-pressure weld. This procedure would be the same if we were using it on Grade A, Grade B, Carbon Moly or any of the carbon steel alloys used in general piping systems today; the only exception would be the preheat or stress-relieving temperatures.

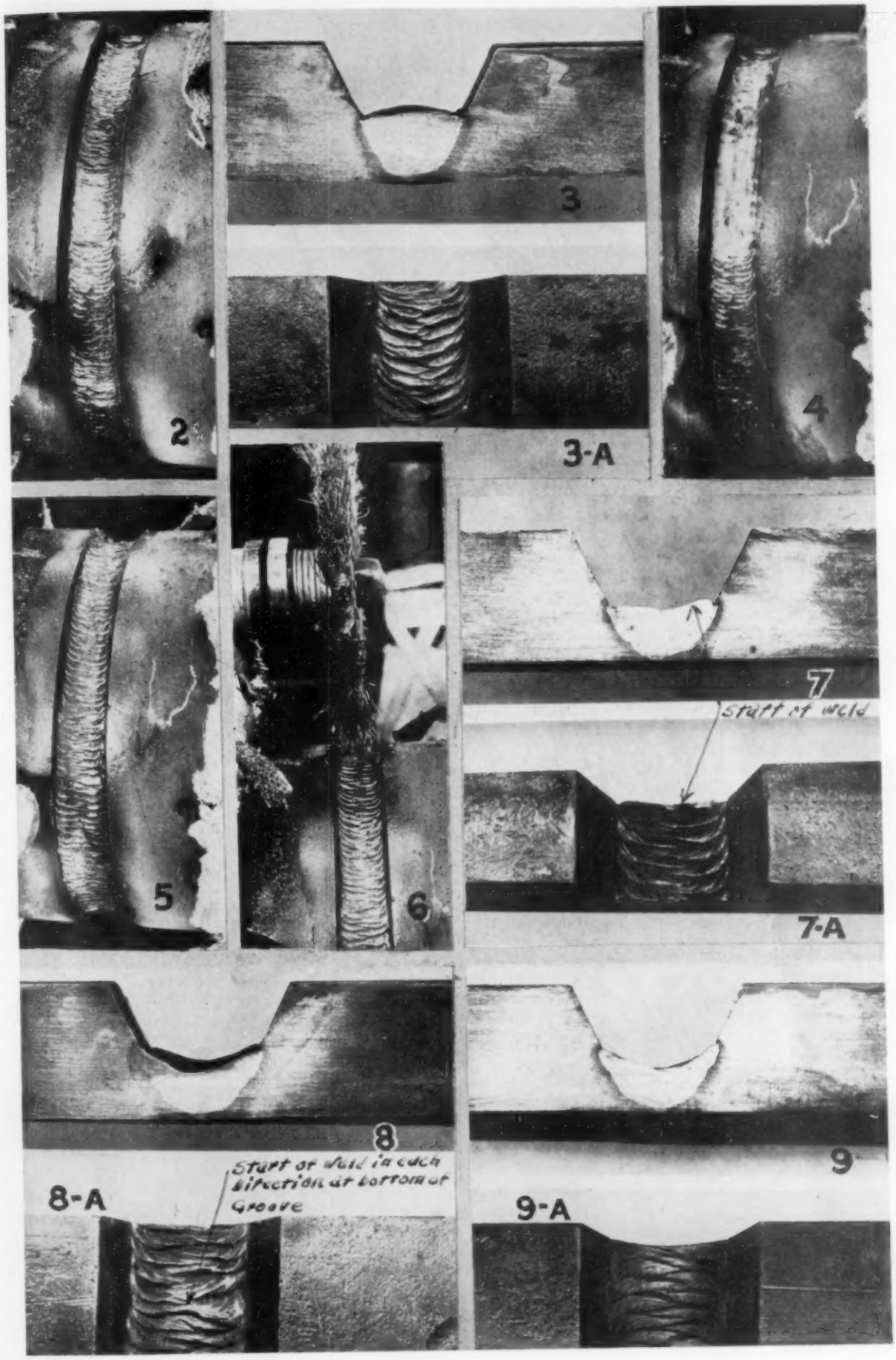
The one problem we are faced with at the present time is just how much chipping is necessary in order to produce a sound weld.

With the proper training of the operator and proper technique, I believe that chipping can be reduced to a minimum, which under the present-day conditions is vitally important.

Figure 1 illustrates a connection which is $8^{3}/_{4}$ O.D. x $^{7}/_{8}$ in. thick, Grade B tube to be used on 900-lb. boiler feed discharge piping for one of our large power-producing companies here in the East. It is set up in such a way that all joints may be welded simultaneously.

You will notice that the preheat is applied by the use of the resistance method which is automatically controlled.

On this particular piece the temperature of the preheat is held between 400 to 450° F. and is held at the temperature from the time the weld is started until it is completed, and if there is an interruption in the welding the preheat would be held unless at least one-half of the


2
3
3-A
4
5
6
7
Start of weld
7-A
8
8-A
Start of weld in each direction at bottom of groove
9
9-A

weld is deposited. You will also notice that with this set up as it is shown it would be almost impossible to use a positioner or any other method of making it possible to weld in a down-hand position.

Figure 2 is a picture of one particular joint of the assembly which we saw in Fig. 1. Our first impression is that this weld looks all right, but now let's pick it apart.

First you will note this weld has a decided convex contour. If we look at the corners of the groove, we can plainly see the slag and dirt in the corners and folds of the metal, which we shall all agree, should be removed before the next succeeding pass is laid down. Usually we would say let's clean it out, but how? We certainly cannot brush it out with a wire brush because the brush will not reach all the way to the bottom of the corners, and if we chip out the corners we only aggravate the condition for the next pass by making it practically impossible for the welder to maintain an even surface without depositing a string bead in the groove on each side.

Figure 3 is a cross-section cut which is a simulation of the shape of that weld showing the convex contour which gives us a better idea of just what we were looking at. Notice what would happen if we were to chip-out the corners and how the uneven surface would hamper the welder. So in order to play safe and give the welder a fresh start, the chipper would have to cut off the top of the weld and thereby sacrifice a good percentage of our deposition.

Figures 4 and 5 show another type of welding that looks decidedly different. You will notice that the metal has an entirely different, cleaner look, no slag or dirt at the sides and a much more even surface. The reason for this is that instead of a convex contour it is concave. With this shape of this surface the weld can be easily cleaned with an ordinary power-driven wire brush.

If a weld is cleaned as shown in Fig. 6 there is no reason for the use of a chipper at all, except on the start of the weld at the bottom where there is a chance of having a small amount of unfused metal.

The condition shown in Fig. 7 should only exist at the one point and that is at the start of the weld, and the welder should be able to correct himself immediately after he is started on the pass as is shown in Fig. 8.

There is nothing mysterious or difficult about this technique in welding (see Fig. 9). The only thing the welder has to do is to wash the sides of the groove. By that I mean that, instead of hesitating and concentrating his penetration in the center of the groove, as they ordinarily do, he hesitates and concentrates at the sides. Therefore his deposition in the center is lower and he does not need the amount of heat concentration in the center to anneal the preceding pass.

Figure 10 shows the finished weld made in position, and I think beyond criticism in so far as soundness and

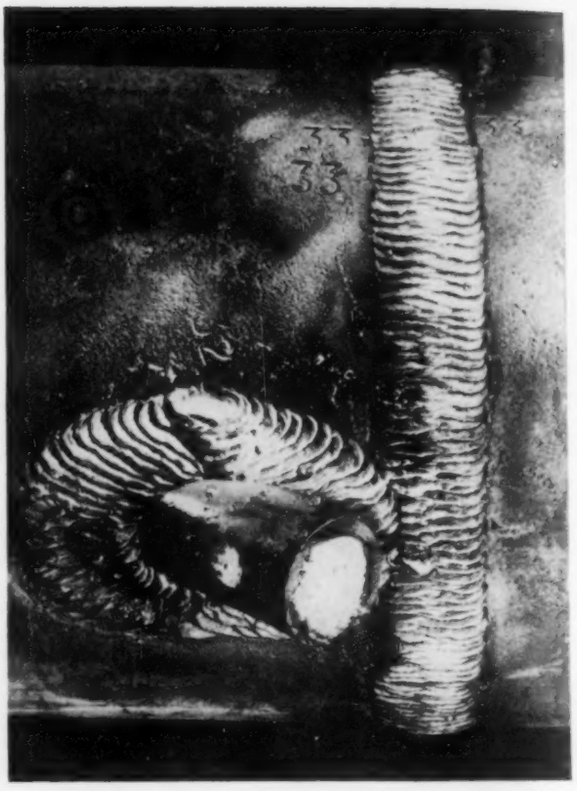


Fig. 10

appearance are concerned, it is as safe as is humanly possible to make it. Regardless of how much chipping you would do you could not make it any better, and I can assure you that the total chipping time would not consummate one-half hour total.

Figure 11 is a picture of the finished section completely welded and stress relieved in the same position it was started in.

Figure 12 is a picture of the welding department of the shop. Notice how the work is set up in such a way that all welds are accessible to the welder without turning and if we did turn the work, how it would tie up the rest of the shop and increase the demand of the crane.

Figure 13 is a picture of a portion of the main shop showing the general layout for bending, vanstoning, layout, setting up and welding. We are equipped to handle pipe up to 30 in. and have welded some of the highest pressure piping systems in operation today. The management of this plant is consistently striving for safety, accuracy of fit and satisfaction to the customer at all times.

either be limited to spot checks or random samples, or else made only when the inspector has reason to believe that code or specification requirements are not being met.

It is always advantageous for an inspector to have had practical experi-

Fig. 11

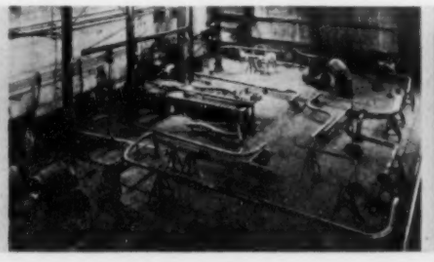


Fig. 12

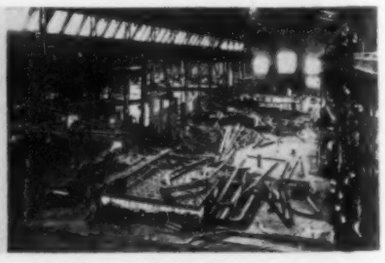


Fig. 13

RECOMMENDED PRACTICES FOR INSPECTION OF FUSION WELDING*

AS IN the case of much fabricated work, that which is done by a welding process is often required to be inspected during the course of construction, either by the purchaser, by the manufacturer or by reason of some legal code requirements. Whatever the reason, inspectors must be employed by either the fabricator, the purchaser or some agency engaged in furnishing inspection services.

In any event an inspector acts in a judicial capacity as the responsible representative of an organization. He must be governed by some form of written requirements for which he is not likely to have been responsible. If he acts for a purchaser, these may be purchase specifications or some construction code. If he acts for a state, municipal or federal agency they may be definite codes which are civil law or departmental rules. An inspector is guided by the prescribed requirements in either accepting or rejecting the work.

It is not possible to specifically cover all methods of welding or all kinds of material. However, the principles set forth herein are quite generally applicable.

While there are certain characteristics desirable in an inspector it is unwise to attempt to lay down any mandatory requirements, hence the section on qualifications of inspectors is intended only to indicate in general terms the desirable aptitudes.

The structures on which inspection is required will vary widely in design and type of welding application so that no one class of inspectors can be expected to be proficient in all of them.

A shop inspector employed by the manufacturer makes certain routine checks of materials, dimensions, workmanship, finish and other details in a manner that will insure that the product meets design requirements. Such inspection is as much a part of production as the necessary machine operations.

Independent inspections must be on a basis different from that of routine shop inspection. It is generally physically impossible for an inspector to check all details of each part of the product. Any such checks must either be limited to spot checks or random samples, or else made only when the inspector has reason to believe that code or specification requirements are not being met.

It is always advantageous for an inspector to have had practical experience in producing the product he inspects. Theoretical or reading knowledge of the work does not inspire the confidence of the manufacturer's personnel that actual working experience does. On the other hand, practical experience alone, without the other necessary qualities, is not sufficient equipment for a capable inspector.

The several sections of this report are so segregated as to make the recommended practices readily available to those interested and are in as much detail as is possible without becoming too elaborate.

The practices among different fabricating shops vary due to location, equipment and various ideas which have been gained through experience, although the final result should be the same. Inspectors who have had experience only in one or two shops should not attempt to convert other fabricators to the practices with which the inspectors are familiar. Should this be attempted, the result is likely to be increased cost of fabrication, confusion due to unfamiliar methods and a general animosity toward the inspector covering the work. The inspector should enter a shop with two main thoughts in mind, namely, to obtain a good job properly fabricated to the applying code or other specification and to expedite the completion and delivery as much as possible. A capable inspector has the advantage of knowing what should be furnished and just what his employer wants, whereas the fabricator, in many cases, is handicapped, particularly in the shop, in not being fully informed and familiar with the product.

Believing that it will be helpful to inspectors, a discussion of the problems encountered in the welding of ferrous and non-ferrous metals has been included.

SECTION I—QUALIFICATIONS OF WELDING INSPECTORS

An inspector should have excellent eyesight, and his physical strength and agility should be sufficient to permit efficient work. He should be familiar with the code which governs the work he is inspecting. The codes most commonly used and generally recognized are those of the Boiler Code Committee of the American Society of Mechanical Engineers, the A.P.I.-A.S.M.E. Unfired Pressure Vessel Code, the A.W.S. Code for Arc and Gas Welding in Building Construction, the A.W.S. Rules for Field Welding of Steel Storage Tanks, the A.W.S. Specifications for Welded Highway and Railway Bridges, the A.W.S. Standard Qualification Procedure and the welding specifications of the bureaus of the Navy Department and War Department. He must, of course, also be familiar with any other specifications under which the work he is to inspect is to be done.

The inspector should have had actual experience in the inspection of welding. It is usually an advantage for him to have had personal experience in welding by either or both the electric arc and oxyacetylene processes. While it is not essential, technical education is very desirable. He should be competent to determine, by observing the actual welding operation, whether an operator is securing proper fusion and penetration.

He should be conversant with filler metal specifications covering electrodes and welding rods and know the limitations of the several grades.

* Prepared by a committee consisting of E. R. Fish, *Chairman*, The Hartford Steam Boiler Inspection and Insurance Co.; L. M. Dalcher, American Welding Society; Bureau of Ships, Navy Department; Perry Cassidy, The Babcock & Wilcox Co.; Everett Chapman, Lukenweld, Incorporated; G. L. Cox, Watertown Arsenal; A. J. Deacon, Bethlehem Steel Co.; F. Eder, R. W. Hunt Co.; F. C. Fyke, Standard Oil Development Co.; I. T. Hook, American Brass Co.; R. C. Kennedy, East Bay Municipal Utility District; A. N. Kugler, National Electrical Manufacturers' Association; Wm. E. McKenzie, Bureau of Ordnance, Navy Department; C. O. Myers, The National Board of Boiler & Pressure Vessel Inspectors; C. W. Obert, The Linde Air Products Co.; J. F. Randall, Combustion Engineering Co.; S. M. Spice, General Motors Corp.; W. G. Theisinger, Lukenweld, Inc.; J. J. Vreeland, Chase Brass & Copper Co.; J. L. Wilson, American Bureau of Shipping.

He should be familiar with the various non-destructive tests for welding and be able to interpret and evaluate accurately the results of such tests.

The inspector's temperament should be such that he is able to cooperate fully with the manufacturer, to the end that the required results are obtained and amicable relations are preserved between the purchaser and the fabricator.

He should have unfailing integrity in the prosecution of the work and honesty in his dealings with the manufacturer.

He should have good judgment in the interpretation and application of code or specification requirements since even the most carefully prepared rules are not always clear or complete.

He should be familiar with the reading of drawings, particularly with respect to understanding of the symbols for welding.

He should have sufficient technical training or experience to realize the possible effect of heat during welding on the strength of the structure and its relation to cracking and other defects. He should know what constitutes a good weld and how to detect any defects that might occur.

He should have ability to prepare complete, concise and readily understandable reports.

SECTION II—DUTIES OF INSPECTORS

In outlining the duties of inspectors on welded fabrication work it will be assumed that they are competent to make the kind of inspections needed for the type of structure to be inspected.

If it is so stipulated in the instructions under which the inspector is working, one of his functions may be to act as intermediary between the customer and the fabricator from the time the plates and other material are ordered until the vessel or other structure is finally completed. Sometimes it may be expedient, although it is rarely a part of his duties, for the inspector to be of service by acting as expeditor of materials from various mills since his familiarity with the job and foresight can thus avoid delays in delivery.

An inspector should be alert at all times, not because the fabricator may intentionally disregard certain requirements but because of errors that may occur through carelessness or lack of familiarity on the part of the fabricator with the customer's specifications or the code to which the vessel is being built.

The duties of the inspector on welded construction will, for most structures, follow the order of fabrication procedure, which generally starts with (*a*) the design and materials to be used, and continues with (*b*) methods of assembly and fitting up, (*c*) checking of the procedure and qualification of operators, (*d*) inspection during construction, (*e*) proof or acceptance tests and (*f*) records. These items are elaborated upon below.

Design and Materials

The inspector should study the design in advance, particularly with respect to the loads to be carried by the several parts and the construction details of the work with special reference to the provisions made for welded fabrication.

It is also important to consider the material used in the structure as some materials, such as alloy steels or the non-ferrous metals, may require special treatment to obtain satisfactory welding. The welding details and materials should be checked by the inspector before fabrication begins, for compliance with the applicable code or specification.

Assembly and Fitting Up

In those cases where it is required the inspector must have opportunity to check the fitting and alignment of parts to make sure that the welds can be applied to meet the requirements of the design and that the stresses will be distributed as intended. He should also carefully follow the welding operations to make sure that warpage and misalignment will be avoided to the greatest possible extent and thus avoid possible rejection.

Procedure and Operator Qualification

It is a fundamental principle that the manufacturer must adopt a definite procedure by which the welding in the shop or field is to be done. This procedure should be such as to deposit weld metal and produce welded joints with acceptable characteristics as called for by the guiding specification or code. It is part of the inspector's duty to witness the demonstration test to prove the sufficiency of the procedure, or to see authentic documentary evidence to that effect. This procedure should be written out, giving in detail all pertinent data such as the type of electrode or rod to be used, the shape of the welding groove, the number and sequence of the several beads, cleaning of slag, peening and the current characteristics for electric welding or the size of tip and nature of flame, forehand or backhand technique, etc., for gas welding.

If the work is to be done under the terms of an established code, the qualification test to demonstrate that the welding procedure to be used is suitable for the purpose will probably have been provided for. It will be required also that the welding operators be checked by suitable tests to determine their ability to apply the procedure selected and obtain sound welds. If, however, the work is not subject to any particular code rules, specifications or contractual requirements may impose some qualification procedures which the inspector should see are properly followed.

Inspection During Construction

Inspections on which acceptance of the welded structure will be based are usually made in the manufacturer's or contractor's shop when the work is of such dimensions that when completed it can be shipped or transported to the installation site. If the work exceeds the limiting dimensions of shipping facilities it must be fabricated at the place of erection, either in whole or by erecting parts and sections that were prefabricated in the shop. In the former case the inspection is all carried on in the field while in the latter the inspection is divided between the fabricating shop and the field erection site.

Inspection of new work in the shop or in the field can be properly made only when there are code requirements or specifications for the guidance of the inspector, together with detailed drawings showing just how the various parts are prepared, shaped and joined together.

It is the welding operator's duty to be guided by the specified procedure when making welds, but prior to doing any work on a welded structure, he must have demonstrated his ability to make sound welds when following the prescribed procedure. It is the inspector's duty to assure himself that

quality through the application of standard tests. The former requires an intimate practical knowledge of welding operations while the latter calls for complete familiarity with the standard American Welding Society tests, which are written in terms of results, independent of the process used.

must have demonstrated his ability to make sound welds when following the prescribed procedure. It is the inspector's duty to assure himself that each welding operator has made a satisfactory qualification test, either by seeing the test made or by checking the results of tests previously made and which should be part of the shop record. Only such operators should be permitted to work on welded structures coming under the inspector's jurisdiction.

Testing

After fabrication is completed it is an important duty of the inspector to check the structure to make sure that all code or specification requirements have been met. This may, in many classes of work, involve some tests or other special treatments. In pressure vessel construction, stress relieving, radiographing, trepanning or hydrostatic testing may be required. For other weldments, one or more of these requirements may be applicable. Pressure vessels and parts are required to be subjected to hydrostatic tests to determine their tightness as well as also to obtain some indication of the strength of the welds.

Records

Work that requires inspection will also require adequate records but whether required or not the inspector should keep full notes of his inspection work.

It is his duty to check the required records to make certain that they are complete, in accordance with the rules, accurate and available when and as required. Records that require the manufacturer's signature should be prepared by the manufacturer.

Records should be in as much detail as the conditions necessitate. It is well to comment on the general character of the work, such as the observance of prescribed tolerances, any difficulties under which the whole or any part of the work may have been performed and any defects that there may have been, whether corrected or not.

The inspectors should see that copies of the records go to the manufacturer, contractor or any others entitled to them, retaining a copy in his own file for future reference.

SECTION III—INSPECTION AND TESTING OF WELDED STRUCTURES

General

The increased use of welding in the fabrication of pressure vessels and other structures has made it necessary for inspectors covering this class of work to familiarize themselves with the many phases of welding in connection with such fabrication.

The inspectors must not only be familiar with the actual welding but should have a knowledge of the material being used, physical testing, shop practices, stress relieving, radiographic examination as well as many other points.

The inspection of welding operations properly falls under two headings: (1) the examination of welding techniques and (2) the evaluation of weld quality through the application of standard tests. The former requires an intimate practical knowledge of welding operations while the latter calls for complete familiarity with the standard American Welding Society tests, which are written in terms of results, independent of the process used. From this it may be seen that the only difference in inspecting arc and oxyacetylene welding operations lies in the inherent differences between the two processes.

The testing of welds is the same for both arc and gas welding. It should be remembered that in all weld testing there are relatively few non-destructive tests. All of the tests employed in qualifying procedures and operators (see A.W.S. Standard Qualification Procedure) are definitely destructive tests and consequently are not practicable for finished structures.

There are several non-destructive tests available—X-ray, gamma ray, trepanning, magnetic powder testing—but unfortunately none of them may be considered universally applicable. These tests are principally qualitative in results, although a measure of quantitative evaluation is possible in the case of X-ray and gamma ray examination.

The X-ray and gamma ray methods of testing, while differing in application and technique of execution, are sufficiently alike in results to permit considering them together.

The pressure test (hydrostatic or air) is suited only to closed containers, such as pressure vessels, tanks, pipes, etc.

The following comments apply principally to welded pressure vessels but the general principles are applicable to any forms of welded structures.

Shop Inspections

1. Materials

The materials used in the fabrication of welded structures must be of a weldable quality and should meet the requirements of the specifications for such materials. These factors should have been thoroughly considered at the time the structure was designed and during the inspection of the raw materials at the mills. If such inspection is provided, it should be seen that the specified requirements are complied with. Lacking inspection at the mill, the mill test reports should be carefully checked. If these precautions are not taken, difficulties which can be attributed to improper materials may be later encountered during the welding.

The plates, shapes, heads, forgings, etc., should preferably be inspected at the various sources of supply, but, wherever inspected, any materials which show injurious defects should be rejected.

The materials should have been tested as to physical properties and these, together with the chemical analyses, should meet the specified requirements. If the finished structure is to be stress relieved or given any special heat treatment, it should be determined that the acceptance tests are made on specimens receiving the same treatment. A record of all test results and analyses should be kept for reference during fabrication and after the structure has gone into service.

If the specifications require the material to be stamped, the inspector should see that the proper markings are applied with steel stamps as these may be required in the course of fabrication or later for identification in the field after the equipment has been placed in service.

The inspection of plate edges by etching or testing, by the gas torch or otherwise, will disclose any discontinuities or laminations which, if present to a marked degree, become a factor contributing to weld defects, particularly with the submerged melt process of welding. Laminations may, in some cases, be chipped out and the groove filled by manual welding before welding the joints.

2. Fabrication

The edges of the plates, shapes, heads or other surfaces where welding is involved should be properly prepared for welding. The most common joints in welding are the butt type, using a V, U or modified U groove, and the fillet type. The root face should be of uniform thickness in order to avoid difficulties during the deposition of the first few beads of weld metal at the bottom of the groove. The uniformity with which this is held lessens the possibility of not removing sufficient metal when chipping for back welding, since the chipper will have a uniform amount of metal to remove.

The edges of rolled plates should have the proper curvature in order to avoid a flat zone along the seam.

After the plates or shapes have been formed to the proper diameter or shape, the fitup prior to welding should be checked to see that the edges are properly butted or fitted and held in place by tack welds or other means.

In fitting up shell sections and/or heads or other parts for welding of the circumferential and other joints, the alignment should be carefully checked to avoid any improper practices which would necessitate lengthy and costly repairs later, with resulting delays in completion.

3. Welding

All welding operators to be employed on the job should be qualified in accordance with the particular specification or code to which the structure is being fabricated. The fabricator's records of operators' qualification tests should be checked to see whether all operators have satisfactorily passed the tests required within the prescribed time limit. A point to be checked in this respect is to see whether each operator has been qualified individually on plates of the thickness being welded and not on a plate made by several operators. It should also be ascertained that welding operators who are to be employed on work not in a flat position or on assemblies such as piping, are qualified for welding in the position in which the work must be performed. This should be gone into thoroughly and each operator employed on the work qualified before welding operations are started.

The type of electrode or rod to be used should be checked. Although there are a number of satisfactory coated electrodes, it is usually advantageous to use the same one throughout the job. The storage room for electrodes should be checked since damp or humid atmospheres can have a detrimental effect on the coating and an unsatisfactory weld result. The welding characteristics of the machines should also be investigated to determine that uniform welds of high quality can be obtained.

The practice in most cases is to weld the seams in pressure vessels on the outside, then back chip and complete the weld on the inside. Care should be taken to see that all unfused metal, cracks, etc., are removed at the bottom of the weld before backwelding, and that the chipped groove is smooth and of the proper contour to permit backwelding without the entrapment of slag, since this is one of the vital points in obtaining a sound and homogeneous weld. In the case of ferrous materials, magnetic powder inspection of the root-chipped groove may be performed in case there is doubt concerning the complete removal of defects in the bottom of the groove. The welding technique for identical jobs will vary in different shops but equally satisfactory results can be obtained. The customer is primarily interested in obtaining a sound weld and a satisfactory product, and it is not a function of the inspector to dictate the technique to be used.

Particularly for heavy plates, high tensile steels or alloy steels, the procedure will probably call for preheating. There are no hard and fast rules for preheating temperatures but in any case the inspector should guard against permitting the metal in the vicinity of the weld to drop to a temperature below that specified in the approved procedure.

Each bead of welding should be thoroughly cleaned of all slag before applying each successive bead. The cleaning operation is essential as many defects in welds can be attributed to improper cleaning. In finishing a weld the last bead should be made so that a uniform, neat looking weld will result. Undercutting should be guarded against and any undercut areas should be repaired by applying a stringer bead over the undercutting, which later should be chipped and ground flush with the plate. The fillet welds of all connections, such as manways, nozzles, attachments, etc., should be at the correct angle and of the proper depth. There is a tendency to apply most of the weld metal of a fillet weld on one leg and have insufficient depth through the throat.

The first layer of fillet welds should be made with an electrode small enough to assure penetration into the root of the joint.

4. Examination of Welds

Many specifications and codes provide for some sort of non-destructive examination of welds, such as X-ray, gamma ray, magnetic powder testing or a sectioning method, as described below.

Radiography, particularly with X-rays, is a common nondestructive method of examining welds. If the equipment is of sufficient capacity for the thickness of plate involved, this examination should reveal any defects or inclusions that are 2% of the plate thickness or greater. As a means of determining this, suitable penetrameters are provided for in the codes. The penetrameters should be properly attached and identified with numbers as to their location. If any film does not show the proper identification numbers or if the required penetrameter indication is not picked up, the radiograph should be retaken.

The technique used in taking X-rays depends largely on the equipment which the fabricator has and what his experience has shown will produce the best results. It is not the function of the inspector to dictate the procedure to be followed provided the films resulting from the fabricator's practice are satisfactory. The manufacturers of X-ray equipment set up certain procedures applicable to their machines. However, in most instances it has been found necessary to vary from these set rules in order to obtain the best results.

The interpretation of radiographic films requires not only a knowledge of welding and welding defects but also the exercise of good judgment as to whether the questionable area is actually a defect. Where a difference

Considerable experience is required to properly apply and judge the results of this method of testing.

5. Stress Relieving

of welding and welding defects but also the exercise of good judgment as to whether the questionable area is actually a defect. Where a difference of opinion exists, rather than cut out the weld, a retake of the areas in question may prove whether the welding is sound or not. Other areas may be questioned that may be the result of a low spot in the weld, undercutting, an inside seam line or other conditions which are not usually considered to be welding defects. In such cases the film should be placed on the weld and the areas in question located on the surface and the necessary corrections made. The removal of slag, cracks, lack of fusion and other obvious defects is seldom questionable and the defective areas must be chipped out, rewelded and re-X-rayed. However, the interpretation of porosity resulting from gas inclusions and the extent to which such porosity can be accepted have constituted a source of some disagreement in the past. This has been largely eliminated through the adoption of standard films by the A.P.I.-A.S.M.E. and the A.S.M.E. Codes, showing what is not acceptable. The use of these standard films, together with a knowledge of welding and the application of good judgment, should result in a satisfactory product and keep any discussions between the fabricator and inspector to a minimum.

When complete X-raying is not specified, the welds may be examined by taking spot X-rays at points indicated by the inspector.

In heavy-wall structures or those where X-raying is not practicable, radium is sometimes used in examining the welds. This is called gamma raying and while the technique of taking the pictures is different, the results are quite similar to X-raying.

Where radiographic equipment is not available, examination is often made by a sectioning method such as trepanning plugs or otherwise cutting samples from the welds. Trepanning is done by means of a special cylindrical saw operated by motor, which is readily obtainable. Another method is to saw from the welded joint a boat-shaped specimen by means of a special spherical saw. The plugs should be taken at those points where the welds look questionable. One of the common points where such plugs are taken is at the intersection of circumferential and longitudinal seams. After removal, the plugs should preferably but not necessarily be sectioned so as to get a plane surface, and be etched and examined for objectionable defects, such as cracks, lack of fusion and inclusions. If any are found defective, additional plugs should be taken at intervals on each side of the defective ones. This should be continued until no further defective plugs are found in the particular seam and all welding represented by the defective plugs should be chipped out, rewelded and retested. Where equipment is available, spot X-raying is preferable. (See Section VI for etching reagents and methods.)

The magnetic powder method of testing may also be employed on finished welded products of ferrous material. The metal part is first magnetized, generally by an external coil or solenoid. The magnetized piece is then covered with finely divided iron particles either by sprinkling or by immersing in a bath of light oil in which the particles of iron are kept in suspension by agitation. A crack or defect in the part, either surface or sub-surface, causes a discontinuity in the magnetic flux lines and the iron particles collect at that point, outlining the defect. Again this is a qualitative test and is limited to those assemblies which permit of magnetization.

Considerable experience is required to properly apply and judge the results of this method of testing.

5. Stress Relieving

After the welding of all seams and attachments has been completed and all welds repaired, the vessel should be stress relieved if required by the code or purchaser. The stress-relieving furnace should be of a type adaptable to the work involved and designed so that the heat will be applied uniformly and in a manner not injurious to the vessel. In the case of thin shells or shells which may be susceptible to some deformation during the stress-relieving operation, they should be braced on the interior so as to minimize the distortion. The vessel should be blocked in the furnace in such a manner as to prevent sagging or bowing during the stress relieving. The rate of cooling of structures which have a great variation in section should be controlled in order that residual stress will not be set up from excessive temperature differentials in the weldment during the cooling cycle.

The fuel used in the stress-relieving furnace should be checked as certain types of fuels cause heavier scaling or greater oxidization than others. The fuel used in a stress-relieving furnace is not for an inspector to decide but it is well for him to familiarize himself with it, and the conditions that may result from its use, such as excessively heavy scaling. Certain elements in fuels may have a deleterious effect on non-ferrous metals, for example, 0.5% or more of sulphur in a fuel will have an embrittling effect on high-nickel materials and therefore should not be used.

The temperature controls, recording charts, location of thermocouples, etc., should be checked to insure uniformity in the heating of the vessel. The temperature used should conform to the applicable code, and the rate of heating, time held and rate of cooling should agree with the prescribed practice.

6. Hydrostatic Testing of Pressure Vessels

After all other processes or operations required by the specification or code have been performed, the vessel should be hydrostatically tested. The test pressure should be that called for by the code, specification or contract. The vessel should be blocked up for testing in such a manner as to permit examination of all parts during the test period. Sagging due to the water load should be guarded against. When filling the vessel with water, care should be taken to avoid all air pockets. The temperature of the water should be approximately the same as, but not lower than, the atmospheric temperature, otherwise "sweating" will result and a proper examination will be difficult. The telltale holes in the reinforcing pads should not be plugged during the hydrostatic test, and all such pads should be tested prior to the hydrostatic test, this test to consist of applying air pressure on the pad through the $^1/_4$-in. tapped opening and slushing soapy water on the welds, both inside and outside. A gage should be so located as to indicate the air pressure applied to the pad.

The hydrostatic pressure should be applied gradually and the gage checked to see that it is functioning properly. If available, a second gage attached to the vessel at some suitable point is desirable in order to check the pressure readings.

If the code or specification requires a hammer test this should be applied in accordance with the requirements. A small curved steel plate placed over the weld during this test will afford some protection to the shell itself. Hammer testing is a controversial subject and present requirements are likely to be changed. Inspectors should be alert to any new action by code committees.

When the time limit of the test has been reached, a final examination should be made of all seams, telltale holes, etc., and, if the results are satisfactory, the pressure can be released.

The use of air for the testing of pressure vessels is discouraged and should not be employed unless the vessel has first been tested with water to a pressure in excess of the air test pressure. In the case of large gas containers not designed to carry heavy loads, testing by air must be resorted to but should be done only in accordance with a prearranged program.

7. Testing Structures in General

In the case of some welded structures, tests may be applied to determine the integrity of both the structure and the welds used in fabricating or repairing it. In structures formed of welded structural shapes, testing may be applied by loading, lifting or perhaps otherwise overstressing the part to determine whether there is the desired margin or reserve strength available therein. However, the specifications usually provide for any testing desired.

8. Final Inspection and Check of Pressure Vessels

After the hydrostatic test, the vessel should be drained and any silt or scale cleaned out and final inspection of the interior and exterior made, as well as a check of the alignment, circularity and general dimensions. The vessel should be leveled as carefully as possible for this check and the measurements should be accurately taken especially in the case of towers or other vessels which contain tray supports or internals where close tolerances must be held.

During the final inspection any welding which has not been properly cleaned should be ground or chipped to give a satisfactory appearance. Any areas where clips or attachments were welded on for testing or handling should be chipped and ground smooth. The welds should be carefully checked for evidence of cracks which might have developed on test.

If the arrangement for the inspector provides for a more general inspection than merely the welding operations, the over-all dimensions, connections, squareness of flanges, facings, drillings, etc., should be checked to see that they conform to the drawings within the permissible tolerances. Spirit levels and protractors should be used and in checking the elevations of connections and manways, the dimensions should be taken from the base line or working point shown on the drawing. Structures that are to be shipped to other points for machining should be carefully checked for dimensions on all surfaces to be machined to assure that sufficient stock is provided. Insufficient stock can readily be added by welding at the point of fabrication, even though it necessitates re-stress relieving, whereas the machining contractor may have neither welding nor stress-relieving facilities. It is often advantageous to deeply center punch bench marks or base lines for the convenience of the layout men in the machine shop or in the field. (Center punch marks should not be left on parts which are to resist dynamic loads.)

Upon completion of the tests and inspection, the vessel should be stamped with the design pressure, allowable working pressure, test pressure, code symbol, etc., as required by the applicable code or specification, along with the inspector's identifying marks. The inspector should see that the manufacturer has prepared and signed the proper record forms, and himself sign them if required, retaining one or more copies together with other pertinent data such as the copies of the stress-relieving charts, test charts, weld test results, material data, etc., which should be retained as a permanent record of the vessel.

Field Inspections

1. New Work

Fabricating new work in the field may be considered as only deferred shop operations, to which the same principles apply as for shop work.

2. Existing Structures

The inspection of existing welded structures is not nearly so definite a procedure as that involved in the inspection of new welded construction. The principal purpose of inspection of existing vessels or other structures is to ascertain the physical condition of the object with particular reference to the welded joints and fastenings. It is important to observe whether they have deteriorated either from over-stressing or corrosion and, of course, signs of weakening of the structure should be carefully looked for.

It is obviously impossible to tell by the appearance of the exterior of a welded joint what its interior condition may be but in many instances the condition of welded seams can be quite definitely determined by trepanned plugs as hereinbefore described. In many cases one of the most dangerous effects is corrosion, either from the particular type of usage or, in the case of a pressure vessel, from the contents of the vessel, either liquid or gaseous. In such case it is important that arrangements be made for the vessel to be emptied periodically and the interior inspected carefully, either by entry of the inspector into the interior or by visual evidence of the interior obtained by looking through inspection openings.

The inspector must use his best judgment in endeavoring to determine the locations of critical stresses and inspect the parts, including particularly the welds, by which those stresses are carried. In the presence of corrosive agents parts of structures that are subjected to high stress are subject to accelerated corrosion. This is particularly noticeable in pressure vessels containing corrosive liquids or gases. The effect is particularly dangerous if the deposited weld metal is porous or not properly placed to assure uniform stress distribution. Any unusual effects observed on the welds or structural members that may have a weakening effect should be carefully noted.

The inspector should also watch carefully for the deformation of parts of the structure which may result from improper loading of the structure or temporary overloading. Usually the effects of such conditions are independent of the welded attachments but unless the welded joints are prac-

tically perfect the concentrated stresses from such loadings are likely to localize at the welds. When such conditions are observed the inspector should report them immediately and recommend that the structure be taken out of service until any condition of localized

existing at the joint are a more frequent source of this defect. If the metal being joined first reaches the melting temperature at areas above the base of the joint, molten metal may bridge

tically perfect the concentrated stresses from such loadings are likely to localize at the welds. When such conditions are observed the inspector should report them immediately and recommend that the structure be taken out of service until any condition of localized weakness can be corrected.

SECTION IV—WELDING CHARACTERISTICS OF FERROUS METALS

Introduction

Since it is impossible to devise rules which will enable an inspector to identify all of the factors likely to cause defects in welds, this discussion will attempt only to describe a few of them briefly. A thorough knowledge of the limitations of a given welding process, coupled with an understanding of the conditions which are likely to promote formation of defects, will better fit the inspector to judge the probability of obtaining joints which are satisfactory for a particular service.

The difficulties arising in the production of satisfactory welded joints in ferrous metals will be separated into two major groups (1) defects likely to occur in all ferrous metals, and (2) defects or other special problems which are related to the metallurgical characteristics of the material.

This discussion applies specifically to the metal arc and gas welding processes, since they are the methods most frequently used for work subject to inspection. Space does not permit a separate discussion of the carbon arc, atomic hydrogen or other processes of welding. However, if the inspector in his training obtains a knowledge of these other processes, the information regarding the causes of defects in the metal arc and gas processes may be useful to him.

Three additional limitations will be placed on the scope of this discussion:

1. Only those materials will be considered which are known to readily permit the production of satisfactory welded joints.
2. A joint design will be considered with which, under test conditions, the process under discussion will produce a satisfactory joint.
3. An electrode or welding rod will be considered which is capable of producing sound metal and of fusing properly to the base material.

Defects Likely to Occur in All Ferrous Metals

The principal defects found in welded joints in all ferrous metals are (1) Incomplete penetration, (2) Lack of fusion, (3) Undercutting, (4) Slag inclusions, (5) Porosity and (6) Cracking.

1. Incomplete Penetration

This term is frequently applied to describe the failure for any reason of the filler metal and base metal to fuse integrally at the root of a joint or, more specifically, (1) the failure of the root face sections of a welding groove to reach the melting temperature for their entire depth, or (2) the failure of the weld metal to reach the root of a fillet joint, leaving a void caused by bridging of the weld metal from one plate to the other.

Although incomplete penetration may, in a few cases, be due to failure to dissolve or flux surface oxides and impurities, the heat transfer conditions existing at the joint are a more frequent source of this defect. If the metal being joined first reaches the melting temperature at areas above the base of the joint, molten metal may bridge between these areas and screen off the heat source (gas flame or arc) before the metal at the root melts. In metal arc welding, the arc will establish itself between the electrode and the closest part of the base metal. All other areas of the base metal will receive heat principally by conduction. If the portion of the base metal closest to the electrode is a considerable distance from the extreme root of the joint, the conduction of heat may be insufficient to raise the metal temperature at the root to the melting point. The same principles of heat flow require that, with the gas process, the flame be so concentrated that the metal at the extreme root of the weld reaches the melting temperature before or at the same time as the metal at points farther from the root.

Incomplete penetration is a particularly undesirable condition if there is any possibility that the root of the weld may be subject to either direct tension or bending stresses. The void or unfused area permits stress concentration which may result in failure without appreciable deformation. Even though the service stresses in the structure may not involve tension or bending at this point, the shrinkage stresses and consequent distortion of the parts during welding will frequently cause a crack to initiate at the unfused section. Such cracks may progress as successive beads are deposited until they extend through almost the entire thickness of the weld.

The most frequent cause of this type of defect is a joint design not suitable for the welding process used or for conditions of actual construction. When a groove is welded from one side only, complete penetration is not likely to be obtained consistently with the metal arc process if (1) the root face dimension is too great even though the root opening is adequate, (2) the root opening is too small or (3) the included angle of a V-type groove is too small. Any of these factors will make it difficult to reproduce test results under the conditions of actual construction. If the joint design is known to be adequate, incomplete penetration may result from (1) the use of too large an electrode, (2) an excessively high rate of travel or (3) the use of insufficient welding current.

The design factors tending to produce incomplete penetration with the gas process are similar to those for the metal arc process. However, it is not generally considered good practice with this process to use joints having no root opening whether a backing strip is used or not. If the joint design is known to be adequate, incomplete penetration may result from (1) the use of an incorrect tip size, (2) too great a welding speed or (3) insufficient preheat.

2. Lack of Fusion

While this term is sometimes applied to the condition previously referred to as incomplete penetration, it is used here in a more restricted sense to describe the failure of a welding process to fuse together adjacent layers of weld metal or adjacent weld metal and base metal. This failure to obtain fusion may occur at any point in the welding groove.

Like incomplete penetration, lack of fusion is caused by (1) failure to raise the temperature of the base metal (or previously deposited weld metal) to the melting point or (2) failure to dissolve, by means of proper fluxing, the oxide or other foreign material present on the surfaces to which the deposited metal must fuse.

Lack of fusion is not a common defect in metal arc welds unless the surfaces being welded are covered with a material which prevents the molten weld metal from fusing to them. Gas welding, if performed by an inexperienced or careless operator, may yield areas of lack of fusion if sufficient heat is not supplied to the base metal (or previously deposited filler metal). Such lack of fusion will be attributable to the use of too small a tip or failure to use supplementary heating when required.

Inspectors should not infer from this brief discussion that it is necessary to melt an appreciable portion of the sidewalls of the groove in order to be certain of securing proper fusion. It is actually only necessary to bring the surface of the base metal to the fusion temperature to obtain metallurgical continuity of the base and weld metal.

Lack of fusion is best avoided by ascertaining that the surfaces to be welded are free of injurious foreign material and by the use of welding operators who have adequately demonstrated their ability to make sound welds.

3. Undercutting

This term is used to describe either (1) the burning away of the side wall of a welding groove at the edge of a layer or bead thus forming a sharp recess in the side wall in the area to which the next layer or bead must fuse, or (2) the reduction in base metal thickness at the line where the last bead is fused to the surface.

Undercutting of both types is usually due to the technique employed by the operator. However, in metal arc welding, different types of electrodes show widely varying tendencies in this respect. With some electrodes, even the most skilled operator may be unable to avoid undercutting under certain conditions. With a specific electrode, too high a current or too long an arc may increase the tendency to undercut.

Undercutting of the sidewalls of a welding groove is not a serious problem and will in no way affect the completed joint if care is taken to properly correct the condition before depositing the next bead. This is best accomplished by using a well rounded chipping tool to eliminate the sharp recess which might serve to trap slag. However, if an operator is sufficiently experienced and knows to what extent subsequent beads will penetrate, chipping is not always necessary. Undercutting at the surface of a joint should not be permitted in its aggravated forms as it may materially reduce the strength of the joint, particularly with regard to fatigue stresses. Fortunately, this type of undercutting is always readily detectable by a visual examination of the surface of the completed weld and can usually be corrected by the deposition of additional metal.

4. Slag Inclusions

This term is used to describe the metallic oxides and other solid compounds which are sometimes found as elongated or globular inclusions in welded joints.

During the deposition and subsequent solidification of weld metal, many chemical reactions occur between the metal, the air and the electrode coating materials or the gases produced by the flame. Some of the products of these reactions are metallic compounds soluble only to a slight degree in the molten metal. Due to their lower specific gravity they tend to seek the upper surface of the molten metal unless restrained from doing so by other conditions.

In gas welding any slag inclusions that may occur will normally be caused by either insufficient or excessive welding temperatures. Too low a temperature may permit solidification to occur before the oxides on the surface of the base metal have an opportunity to float to the surface of the weld. Too high a temperature or an oxidizing flame may produce excessive quantities of oxide which will not all be removed from the weld.

When welding by the metal arc process using covered electrodes, some slag may be formed by reactions below the surface of the molten metal, slag may be forced below the surface by the stirring action of the arc or slag may flow ahead of the arc causing the metal to be deposited over it. When slag is once present in the molten metal, from any cause, it tends to rise to the surface by virtue of its lower density. Any factors such as high viscosity of the weld metal, rapid chilling or too low a temperature may prevent its release. When weld metal is deposited by the metal arc process over a sharp V-shaped recess, such as that produced by a diamond point tool, slag will frequently be found trapped in the weld. Under such conditions, the arc may fail to raise the bottom of the recess to a sufficiently high temperature for the metal to fill it and allow the slag which was ahead of the arc to float out. A similar condition exists if a sharp recess is present due to undercutting by the previous bead. Slag inclusions of this type are usually elongated, and if individual inclusions are of considerable size or are closely spaced they may reduce the strength of the joint. It is usually not desirable to remove small or isolated inclusions.

Slag forced into the metal by the arc or formed there by chemical reactions usually appears as finely divided or globular inclusions. Inclusions of this type are likely to be a particular problem in overhead welding.

The majority of slag inclusions may be prevented by proper preparation of the groove before each bead is deposited, using care to avoid leaving any contours which will be difficult to penetrate fully with the arc. Obviously, the release of slag from the molten weld metal (except in the case of position welding) will be aided by all factors which tend to make the metal less viscous or retard its solidification, such as preheating and high heat input per inch per unit time.

5. Porosity

This term is used to describe the globular voids free of any solid material which are frequently found in welds. In reality they are another form of an inclusion resulting from the chemical reactions taking place during welding. They differ from slag inclusions in that the voids contain gas rather than a solid.

The gases forming the voids are derived from (1) gas released by the cooling weld metal because of reduced solubility as the temperature drops, and (2) gases formed by chemical reactions in the weld.

The porosity normally found in metal arc welds produced by covered electrodes or in gas welds does not have a serious effect on the mechanical properties of the joint unless present in excessive quantity.

Formation of porosity is most readily prevented by avoiding (1) over-heating of the weld metal (gas process), (2) excessive currents or (3) excessive arc lengths. Too high a metal temperature increases unnecessarily the

2. Hardness and Brittleness

Hardness and brittleness in welded joints are metallurgical effects produced by the heat cycle of welding and are among the chief factors which

ing of the weld metal (gas process), (2) excessive currents or (3) excessive arc lengths. Too high a metal temperature increases unnecessarily the amount of gas dissolved and which will be available for release from solution upon cooling. High consumption of the deoxidizing elements of the coating may take place during deposition if excessive currents and arc lengths are used, leaving insufficient quantities available to combine with the gases in the molten metal during cooling.

6. Cracking

While cracks sometimes occur in thick sections of low tensile strength material because of small defects such as minor cases of lack of fusion, slag inclusions, etc., their tendency to form is primarily related to the metallurgical characteristics of the steel. Therefore, cracking will be discussed in detail under the following section.

Conditions Related to the Metallurgical Characteristics of the Filler and Base Metal

Separation of materials into groups having generally similar metallurgical characteristics will permit a simplified study of the effect of these characteristics upon certain conditions produced in welded joints, namely, hardness, brittleness and cracks. It will also be useful to consider certain corrective measures, such as preheating and stress relieving, which can be employed to minimize the undesirable effects of these conditions. It is important for the inspector to know under which group the steel being welded belongs.

1. Material Groups

Although an ideal separation of the ferrous metals into groups having similar responses to welding operations must await a satisfactory definition of the term weldability and the development of suitable tests to measure this property, an approximate classification will be useful for the purposes of this discussion. Accordingly, the ferrous metals will be divided into four groups: (1) low carbon steels, (2) medium carbon steels, (3) low alloy steels and (4) high alloy steels. Each of these groups will be defined as follows:

1. *Low Carbon Steels.*—Unalloyed steels having 0.30% carbon max., 0.70% manganese max. and 0.30% silicon max., or unalloyed steels complying with the formula and other limitations given for Group P Number 1 of Table 5 of the A.W.S. Standard Qualification Procedure.
2. *Medium Carbon Steels.*—Unalloyed steels having 0.35% carbon max., 0.90% manganese max. and 0.30% silicon max., or unalloyed steels complying with the formula and limitations of Group P Number 3 of Table 5 of the A.W.S. Standard Qualification Proce ure.
3. *Low Alloy Steels.*—Steels listed in Group P Number 4 of Table 5 of the A.W.S. Standard Qualification Procedure.
4. *High Alloy Steels.*—Steels containing more than 3% of alloying elements which are normally used because of superior corrosion or high-temperature oxidation resistance.

2. Hardness and Brittleness

Hardness and brittleness in welded joints are metallurgical effects produced by the heat cycle of welding and are among the chief factors which tend to cause cracking. While a complete discussion of the metallurgical properties of the various metals is beyond the scope of this chapter, a rudimentary knowledge of the tendency of the various groups of materials to harden or become brittle will be of value to the inspector.

It can be said of the first three groups that the hardness and, roughly speaking, the ability of the materials to deform without rupture will depend upon the group to which they belong, i.e., low carbon, medium carbon or low alloy, and also the rate at which they cool from the elevated temperatures produced by the welding operation. The rate of cooling will obviously depend upon a number of physical factors such as (1) the temperature of the base metal, (2) the thickness and thermal conductivity of the base metal, (3) the heat input per unit time at a given section of the weld and (4) the atmospheric temperature. With a given cooling rate the materials in the low carbon steel group will harden considerably less than those of the medium carbon group. The low alloy steels included in the third group will exhibit a wider variation in their hardening characteristics and some of them may be similar to the low carbon group while others will react like the medium carbon group.

The high alloys must necessarily be given separate consideration since this group includes the so-called martensitic steels which behave similarly to the medium carbon and low-alloy groups except that they harden to a greater degree with a given cooling rate, and also includes the austenitic and ferritic stainless steels. Neither the austenitic steels, of which the common 18% chromium–8% nickel stainless steel is an example, nor the ferritic steels, of which the low carbon straight chromium steels (or irons) containing 18% or more of chromium are an example, harden upon quenching from elevated temperatures. However, the ferritic steels in general are rendered brittle (but not hard) by welding operations.

3. Cracking

Cracking of welded joints results from the presence of localized stress which at some point exceeds the ultimate strength of the material. When cracks occur during, or as a result of, welding, little deformation is usually apparent.

It is well known that materials which will exhibit considerable ductility when subjected to uniaxial stress may, when subjected to two- or three-dimensional stresses, fail without appreciable deformation. Shrinkage caused by welding operations frequently sets up multi-directional stress systems. If because of such stresses a joint, or any portion of it, is incapable of sustaining appreciable deformation without failure, additional stresses set up in deposition of subsequent layers or in the welding of other joints may force this part to deform and cause failure.

Cracks in welded joints which appear during welding are rarely caused by multi-directional stresses alone. However, experience has indicated that even though such stresses do not cause cracking, they may, particularly in the case of heavy or complicated structures, cause failure to occur with little deformation when additional load is applied. To avoid this

undesirable condition, stress relieving is usually specified for important structures fabricated of heavy material.

An unfused area at the root of a butt joint may result in cracks without appreciable deformation if this area is subjected to tensile stress. In welding two plates together the root of the joint is subject to such a tensile stress as successive layers are deposited, and, as already stated, a partially fused root will frequently permit a crack to start which may progress through practically the entire thickness of the weld.

After a welded joint has become cold, cracking is more likely to occur if the metal is either hard or brittle. Obviously, a ductile material will withstand multi-directional stresses and stress concentrations which would cause a hard or brittle material to fail.

4. Heat-Treating Operations

Of the various heat-treating operations, preheating and stress relieving are those most frequently employed to reduce the tendency of welded joints to fail by cracking.

Preheating reduces the temperature difference between the base metal and the filler metal which, to some degree, decreases the magnitude of the shrinkage stresses caused by the contraction of the weld. In the case of heavy sections or of materials that become brittle due to the heat cycle of the welding operation, this reduction in shrinkage stresses may be of considerable importance in preventing cracking. Steels in the low carbon group require preheating only under special conditions. With the medium carbon and many of the steels in the low-alloy group, preheating is highly desirable, and with the martensitic high alloys it is likely to be absolutely essential to the production of joints free of cracks. If a sufficiently high temperature is used, preheating may also reduce the final hardness obtained in the welded joint. However, in order to accomplish this, the preheating operation must reduce the cooling rate of the weld and adjacent base metal sufficiently to minimize, or eliminate entirely, the formation of martensite (the hard brittle constituent obtained upon rapid cooling of many carbon and alloy steels from an elevated temperature).

In the case of steels which harden upon welding, stress relieving performs a dual function: first, it relieves the residual stresses produced by welding, and second, it softens the weld and adjacent base metal and restores its ductility. While preheating is primarily effective in preventing cracks during the welding operation, stress relieving is effective in reducing the occurrence of brittle fractures after completion of the weld or in service.

SECTION V—WELDING CHARACTERISTICS OF NON-FERROUS METALS

Copper and Copper Alloys

The inspector should be familiar generally with the welding of copper and copper alloys, methods of qualifying welding procedures and operators and methods of testing welds. He should also be familiar with the specifications or codes governing the particular work which he is to inspect. Some of the things to be observed in carrying out the inspection are the following:

Appearance of Weld.—The weld should have a neat appearance, be uniform in width and in height and contour of reinforcement. A localized increase in width of weld may mean excess heat at that point or an improper repair—a covering up of a leak instead of gouging and rewelding.

Whenever possible, the inspector should examine the underside of a butt weld for correct penetration. Where too much metal has sagged through the joint (no back up) particular inspection should be given for a distance of approximately 2 in. each side of the icicle. Usually radial gas holes are present (particularly true with silicon bronze). The amount of sagging should not exceed $^3/_{16}$ in.

Undue distortion of the plates may mean improper jigging or indicate locked-up stress or relief of same.

Undercutting, Cold Laps.—As copper and high copper alloys are very fluid at fusion-welding temperatures, there is some danger that the vertical face of an arc fillet weld may be undercut and undercutting may also occur on the far side of a vertical gas butt weld. Cold laps may occur on the front edges of a vertical butt or fillet weld and on the lower surface of a horizontal gas or arc fillet weld.

Cracks, Unsoundness.—As in ferrous metals, internal cracks and unsoundness will be spotted most effectively with the X-ray. However, the inspector can generally detect any serious defect of this character. Cracks coming to the surface can generally be spotted. A 7- or 10-power hand magnifying glass is a distinct aid in such inspection. Where there is any doubt a chip taken with a round nose chisel driven along the center line of the supposed crack will decide. If the chip separates like a ram's horn, the crack is proved while if it holds together there is no crack.

A similar test at the edge of the weld will prove correct or inadequate fusion.

Cracks may sometimes be spotted by the kerosene-chalk test. This test is made by flooding the surface suspected of having cracks, with kerosene. After removing the surplus kerosene the surface is covered with a mixture of chalk powder in water or whitewash. After this is dried the kerosene in the cracks will be absorbed by the chalk and become evident because of the consequent discoloration. This test should be undertaken only by one who is familiar with the technique of carrying it out properly.

The gouging chisel is also useful in proving or disproving gas porosity. If there is any suspicion of unsoundness from a close inspection of the surface, a chip may be taken and the chipped surface inspected as well as the fracture at the end of the chip for porosity.

If any cracks or unsoundness be discovered in a weld in a pressure vessel, the same should be chipped out and rewelded. Weeps in copper alloys do not corrode tight as is often the case in ferrous welds. Caulking is also unsatisfactory in closing up minute porosity in copper or copper alloys.

Oxidized Weld Metal.—A heavy black scale on the weld surface may indicate undue exposure of the metal at high temperature. Oxide in the metal is usually indicated by brittleness in the weld metal. It is rarely found in copper-silicon or copper-zinc alloys but may occur in arc-welded copper mostly in the top of the bead or in gas-welded electrolytic copper in a narrow zone at the edge of the weld. It may occur in phosphor bronze or the cupro-nickels if there is an inadequacy of the deoxidizer in the filler rod, and in aluminum bronze it may occur as a thin web which interrupts the continuity of the fused metal.

In any case, the oxidized metal can usually be spotted by chipping the location and noting the ductility as indicated by the chip. Oxidized metal will break off short while clean metal will show a reasonable degree of

cerns the impregnation of the casting under pressure with sodium silicate or a phenolic resin. In most cases chipping and rewelding castings which show seepage leaks will merely extend the leaking area. Repair opera-

In any case, the oxidized metal can usually be spotted by chipping the location and noting the ductility as indicated by the chip. Oxidized metal will break off short while clean metal will show a reasonable degree of ductility.

Entrapped flux will usually occur, if at all, in the area at the edge of the weld. It can be discovered only by chipping or with the X-ray.

In the case of silver brazed or soft soldered copper or brass tube in wrought copper or cast brass fittings, the inspector will have to decide from the appearance of the metal and the solder fillet as to whether the job has had the correct temperature.

In butt-welded or bell-and-spigot brazed (bronze-welded) brass or copper pipe, the appearance of the weld is usually sufficient evidence of a workmanlike job though the inspector can spot "icicles" under the butt joint only by looking or feeling inside the pipe.

Aluminum and Aluminum Alloys

External Inspection—Visual.—Fusion welds in aluminum alloys are inspected visually with or without low magnification for cracks, penetration, undercutting, size of reinforcement and flux removal. Remarks under Copper and Copper Alloys relating to these several items also apply here.

Internal Inspection.—X-ray examination of fusion welds in the aluminum alloys can be accomplished to show porosity, lack of penetration, voids and other non-uniformity in the weld structure with the exception that oxide films do not appear clearly. In view of the fact that oxide films may be included in a weld if incorrect technique is used in making the joint, and may substantially reduce the strength, it follows that X-ray examination should be coordinated with additional tests made by trepanned plugs or nick break tests on welded prolongs or cut-outs from the joints. Microscopic or visual examination of the weld structure on these specimens will show up oxide inclusions.

Mechanical Tests.—In many applications, liquid or gas-tightness of the joints is essential and a proof test on the design assumptions desirable. In such cases pneumatic pressure tests are applied where pressures up to 8 pounds per square inch will provide an adequate test on vessels smaller than 100 gallons. Liquid-tightness is established by immersing the part in water or painting the joints with a light oil or a soap suds mixture. For higher pressures and larger vessels hydrostatic pressure tests are advisable.

In addition to pressure tests the tensile strength of reduced-section specimens, elongation, free-bend and nick-break tests are sometimes made on welded prolongs or cut-outs from the welds. Such tests are not usually conducted except in special cases.

Repairs.—Repairs to fusion welds, where cracks, undercutting and lack of penetration are concerned, should be made by chipping out the defective area and rewelding. Lack of sufficient reinforcement can be repaired merely by rewelding. Where low pressures are concerned small leaks in welds in commercially pure aluminum and aluminum-manganese plate are frequently stopped by peening. In addition to being the most economical this method does not introduce distortion, which may occur from making welded repairs.

Another method of importance when welding aluminum castings concerns the impregnation of the casting under pressure with sodium silicate or a phenolic resin. In most cases chipping and rewelding castings which show seepage leaks will merely extend the leaking area. Repair operations, consequently, are made by a sealing operation rather than a rewelding operation.

Nickel and Nickel Alloys

In general, all information contained in the foregoing parts of this report, dealing with Inspection and Testing of Welded Structures, Materials, Fabrication, Welding, Examination of Welds, Stress Relieving, Hydrostatic Test, Final Inspection and Check, Field Inspections, and Defects Likely to Occur in All Ferrous Metals, applies with equal force to the inspection of structures and equipment fabricated of nickel, monel or other high-nickel alloys.

Visual Inspection.—Fusion welds are inspected visually with or without low magnification for cracks, undercutting, penetration, size of reinforcement and flux removal.

X-ray Inspection.—X-ray examination of fusion welds in nickel and nickel alloys will disclose soundness, degree of penetration, slag inclusions and uniformity of weld structure. The defects which are found should be removed by chipping and rewelding. The same standards that are used for steel may be used for judging nickel and high-nickel alloys.

Mechanical Tests.—The usual tensile, free- or jig-bend, nick-break or other mechanical tests may be made as required. Pressure tests of vessels are made using air or water as the circumstances dictate.

Repairs.—Defects in welds should be removed by chipping and rewelded. Peening is not an effective method of repairing leaks in nickel or nickel-copper alloys.

SECTION VI—ETCHING REAGENTS

This section lists a number of etching solutions suitable for carbon and low-alloy steels as well as for the more common non-ferrous metals and alloys. The manner of applying the solutions is indicated.

To preserve the appearance of the etched specimens they should, after etching, be washed in clear water, the excess water removed, then immersed in ethyl alcohol and dried. The etched surface may then be preserved by coating with a thin clear lacquer.

Etching Reagents for Carbon and Low Alloy Steels

Hydrochloric Acid.—Hydrochloric (muriatic) acid and water equal parts by volume. The solution should be kept at or near the boiling temperature during the etching process. The specimens should be immersed in the solution for a sufficient period of time to reveal all lack of soundness that might exist at the cross-sectional surfaces.

Ammonium Persulphate.—One part of ammonium persulphate to nine parts of water by weight. The solution should be used at room temperature and should be applied by vigorously rubbing the surface to be etched with a piece of cotton saturated with the solution. The etching process should be continued until there is a clear definition of the structure of the weld.

Iodine and Potassium Iodide.—One part of powdered iodine (solid form), two parts of powdered potassium iodide and ten parts of water, all by weight. The solution should be used at room temperature and brushed on the surface to be etched until there is a clear definition or outline of the weld.

Nitric Acid.—One part of nitric acid and three parts of water by volume. (*Caution:* Always pour the acid into the water. Nitric acid causes bad stains and severe burns.) The solution may be used at room temperature and applied to the surface to be etched with a glass stirring rod. The specimens may also be placed in a boiling solution of the acid but the work should be done in a well ventilated room. The etching process should be continued for a sufficient period of time to reveal all lack of soundness that might exist at the cross-sectional surfaces.

Etching Reagents for Non-Ferrous Metals and Alloys

Chromium-Nickel Alloys.—Hydrochloric (muriatic) acid and water equal parts by volume. The solution should be used at a temperature of approximately 160°F. Another reagent uses 2 parts of concentrated sulphuric acid, 1 part of concentrated hydrochloric acid and 3 parts of water, by volume. This solution should be used warm.

Copper and Copper Alloys.—A 25 to 50% solution of nitric acid. The solution should be used cold but it will heat up as used. The etched part should afterward be dipped in a one-to-one solution of concentrated hydrochloric acid and water.

Aluminum and Aluminum Alloys.—Ten parts of hydrofluoric acid, 15 parts of hydrochloric acid and 90 parts of water. The solution should be used at room temperature. The specimen should be immersed in the solution for 15 to 20 seconds, washed in warm water and then dipped in concentrated nitric acid.

Monel.—Equal parts by volume of water and concentrated nitric acid. The solution should be used at room temperature. The specimen should be immersed for 5 to 10 seconds or for a sufficient period to produce a clear definition of the structure of the weld.

Nickel.—Concentrated nitric acid. The specimen should be immersed in the solution at room temperature until there is a clear definition of the structure of the weld.

Inconel.—Aqua regia. The solution should be used warm. The specimen should be first warmed in hot water and then immersed in the solution until there is a clear definition of the structure of the weld. If the weld does not etch readily a small amount of cupric chloride may be added to the solution.

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Fabricated Stainless Steel Tubing

By H. S. Card*

CHOICE of alloy steels for the coolant circulating system of a recently developed liquid-cooled aircraft engine recognized the dual advantage of high strength and high resistance to corrosion in this application. A study of the preliminary designs indicated that it would be most economical to make the component parts of the system from welded 18–8 tubing. This tube is made by a forming and welding process which starts with coiled 18–8 strip of the desired wall thickness and converts it to the tube form in a continuous mill operation.

Reference to Fig. 1, which illustrates five typical parts of the assembly, shows that the tubing undergoes a considerable variety of fabrication. Forming operations include bending, tapering, expanding and flaring. Also, welding is used to join tube bends and to join bolting flanges to outlets and inlets. Therefore, it was necessary to examine the welding and mechanical working properties of the material, as well as the metallurgical effects of these fabricating operations. Consultation with a welded tube manufacturer resulted in several advantageous minor changes in the first design and the adoption of tubing specifications favorable to economical and safe construction.

This open-minded approach to questions of design and fabrication, taking advantage of the knowledge and experience of suppliers, is nearly always essential to satisfactory production when the material is outside the range of commonplace shapes of low carbon steel. Disappointments and delays can easily result from neglecting very simple rules, or from arbitrary choice of dimensions which may be more convenient than vital. On the other hand, intricate parts like those illustrated can be made to meet very close tolerance requirements by consulting the fabricator and ascertaining in advance what the maximum and minimum limits should be on the various items involved.

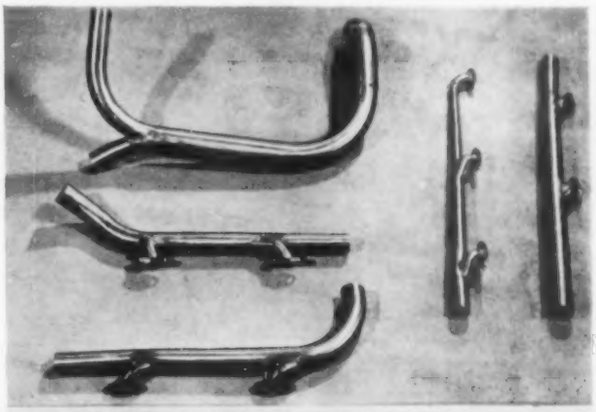
For example, in several of the parts shown it is necessary to join machined bolting flanges to formed pieces of tube. If these are finish machined to final size before welding it is extremely difficult to control the welding technique so that the whole part will fit into its place in the assembly without further machining. It is much easier to make the welding assembly with semi-finished flanges and do the machining thereafter.

Engineers of Alloy Manufacturing Co., Pittsburgh, Pa., were consulted on this fabrication problem, as a preliminary to preparing final specifications for the tube fabrication. A study of the plans showed several items which involved one bend in one plane interlocked with another bend in another plane without any tangent interval. As a forming and bending operation this is impossible unless done with a drop die. However, by forming the desired bends in different pieces of tube and welding the bent tubes together, the desired shapes were produced with reasonable speed and cost, with the bends falling in the planes designated. (This type of welding operation can usually be avoided by further redesign when volume production warrants it.)

Each detail of the design was thus examined from the standpoint of the fabrication methods that were involved, and parts were produced that might otherwise have been classed as impractical with 18–8 material and a wall thickness of 0.032 in. Some of the small outlets were bent at a $^5/_8$-in. radius, which is considerably below general practice.

It is apparent that the limitations on the fabrication of welded stainless steel tubing are no more severe than on other types of tubing, and that scrap losses are greatly minimized by taking advantage of this fact. Also, the designer will come out best by consulting freely with material sources and production departments, prepared to compromise wherever possible on details wherein satisfactory production may be facilitated.

Fig. 1—Parts Which Required Several Combinations of Fabricating Operations



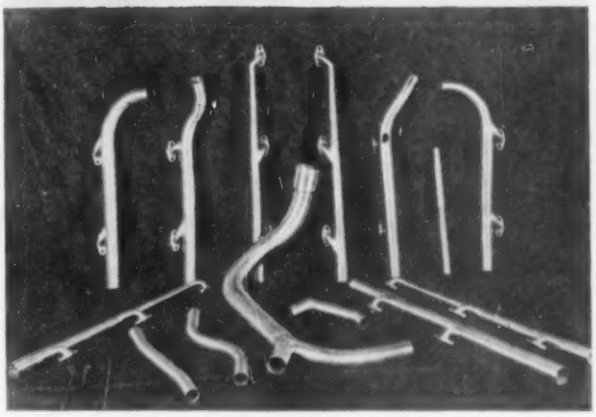


Fig. 2—A Group of Typical Component Parts of Engine Coolant System

* Formed Steel Tube Institute, New York, N. Y.

THE AMERICAN WELDING SOCIETY

ACTIVITIES — RELATED EVENTS

THE PRESIDENT'S MESSAGE

The American Standards Association has recently entered into contract with the federal government for the preparation of emergency war standards. The agencies cooperating with the A.S.A. are the OPA and the WPB—both new agencies built up for the administration of war production controls. Neither the War nor the Navy Departments are parties to the contract.

So far as raw materials are concerned the WPB and the OPA are in a position to force the adoption of emergency standards for materials not entering directly into war products and to influence the specifying of materials from which war products are built. Beyond that this contract can exert little influence.

War products include many units which have been developed and fabricated primarily for industrial use. The standardization of such products has been carried on by industry and the government has adopted parts of those standards. But frequently government engineers maintain that there are special requirements which prevent the acceptance of industrial practice. Undoubtedly many of these claims are fully justified but in many cases a careful analysis would have resulted in the acceptance of the industrial standard.

Military materiel is for the most part non-industrial in design and construction. The national military policy since World War I concentrated the design and production of war materiel in government plants and held production to negligible quantities through limitation of appropriations. Under such conditions full standardization, of course, was not accomplished. It should be noted that the A.S.A. contract does not cover these special products which are not under the control of either of the agencies mentioned.

It is government practice to specify the end product giving the producer freedom in the choice of methods of processing and of fabricating. This ideal has been departed from to a considerable extent in some specifications and the effect of the policy has been mitigated by giving bidders and contractors detail information of the methods of production used at government plants. But these and other conditions have resulted in the government bureaus utilizing only to a small extent the work of the national technical standardization bodies.

Standards are normally looked upon as a protection to the consumer and the general public. The Boiler Code may be cited as such a standard. Producers have recognized the value of standards in eliminating unfair competition of producers who are unable or unwilling to conform to good production practice. At present with rapidly expanding production this is not a question. There are other phases of this problem which should be of concern to producers.

Many contractors forced to subcontract portions of their work, have experienced difficulties in controlling quality of work in plants which have had no previous experience on similar work. Standards and recommended practices would have been of the greatest assistance to such subcontractors.

The lack of standards leads to marked variations in practice among producers. Even though the government is the sole consumer standard practices cannot be maintained under inspection practices which are as at present widely decentralized and depend upon the intelligence and experience of the local inspector. In an industry expanding so rapidly from small beginnings divergencies in production and inspection practice are difficult to control.

Many manufacturers seek changes of drawings and specifications to permit the utilization of more efficient methods of processing—especially those of recent development. If producers were united upon standards for these new methods of production they would find a greater willingness on the part of government officials to accept their recommendations.

There are many industrial corporations possessing highly capable technical staffs which have carried the level of technical development beyond that reached by other units of industry. Especially at present these more fortunate organizations recognize their duty to assist less experienced producers. But such help cannot be given until requested, and often does not come until much economical waste has been incurred. An effective method of rendering technical assistance is the preparation of standards and recommended practices.

This country has not and will not develop super leaders who can direct the industrial war effort without the complete cooperation of all industry. The aims and policies of the government are known. The execution of these policies may be accelerated by intelligent decentralized effort. Standardization is one of the fields in which work originated and planned by technical bodies set up by industry can be of great value in the war program. Government cooperation is essential to the success of the work. The initiative in organizing the work should be taken by industry as it far more fully appreciates and understands the problem. The fact that the government is the consumer should not delay the undertaking. The whole nation is interested in maintaining the quality of munitions and in reducing the cost of production to a minimum.

G. F. JENKS

A COMMUNICATION

The SOCIETY takes great pleasure in reproducing copy of a letter by one of our members, Mr. E. M. T. Ryder, to Professor C. F. Scott of Yale.

July 22, 1942

Re: *Consider the Past, Keep Looking Ahead*

Prof. C. F. Scott,
Sterling Tower, Yale Station,
New Haven, Conn.

Dear Prof. Scott:

Your letter of the 14th is at hand with its urge to the "old grad" to share with the undergraduate "points of view gained from ... experience," and let me add, to do so without preaching.

The world of industry today has more specialists than ever before and there is the same pressure as in 1896 that while an education should be based on fundamentals it should also carry some knowledge of important specialties.

An outstanding example of this has become increasingly obvious and seems now to occupy almost the entire horizon of the war effort. I refer to the welding of metals by modern methods, a process that was not even dreamed of when I was an undergraduate.

Two days ago the second edition of the handbook of the AMERICAN WELDING SOCIETY came to my desk. Sixteen hundred pages cram packed with information covering fundamentals, processes and applications in forty-four chapters in which hundreds of experts have cooperated, resulting in a compendium which we may call worth its weight in gold but which may even contain the key to liberty.

Today the morning papers show the photograph of the last riveted tank built in America under British designs for delivery to them. It is to be succeeded by American designed *welded* tanks which can be built in far less time and will be far more efficient in service. On the West Coast a 10,000-ton welded cargo ship has been built in forty-five days, a speed undreamed of even two years ago. The airplane is absolutely dependent on welding for its wings.

Let me quote from Chapter 1 of the *Welding Handbook*, "welding involves more sciences and variables than any other industrial process .... Physics, chemistry

HOW Bronze repair welding overcomes serious production problems

Anaconda 997 Low-Fuming Rod repairs this fractured press gear for punching artillery shell discs . . . has vital press back working inside two weeks . . . saves several months delay for replacement.

When this large gear on a press punching out shell discs cracked and groaned to a stop, it was apparent that a new gear could not be obtained for several months. But production was interrupted for only two weeks—thanks to repair welding with Anaconda 997 Low-Fuming Rod. The Hebeler Welding Company of Buffalo, New York, well-known specialists, did the job using 125 pounds of rod and 900 feet of air and gas. Chipping and welding required but 55 man hours.

This is but one of countless instances where Anaconda Welding Rods including Anaconda 997* and Tobin Bronze* have saved invaluable production time in war essential industries. Consider their use before scrapping any important machinery that seems beyond salvage. 4899

*The trade-marks "Anaconda" and "Tobin Bronze" are registered in the U. S. Pat. Off.

ANACONDA

Anaconda Welding Rods

THE AMERICAN BRASS COMPANY—General Offices: Waterbury, Connecticut

Subsidiary of Anaconda Copper Mining Company • In Canada: ANACONDA AMERICAN BRASS LTD., New Toronto, Ontario

and metallurgy ... heat, mechanics, elasticity, plasticity, electricity and magnetism ... the electric arc ... optics, including polarized light, X-rays, X-ray defraction, crystal theory and the constitution of matter."

The precaution is given that in the effort to understand this problem we should remember that Lord Kelvin once said in substance if not in words that "mathematics is of no earthly use till it has been turned into arithmetic," meaning, I take it, the tie between theory and practice.

Perhaps we can condense the idea in this letter to a motto, "consider the past but keep looking ahead."

No undergraduate need doubt that this caution applies not merely to welding or industry or science but equally to every field of human endeavor and speculation.

We cannot measure the problems ahead of us but we do know that we must put into the fight every bit of strength, knowledge and imagination that we possess.

Yours very truly,

E. M. T. RYDER

P. S. Since you so insistently demand a "poem" here is one for your private edification or irritation as the case may be.

HOW FIRM A FOUNDATION

or Poetry vs. Noise

"How firm a foundation"—
We sang through the hall,
Thinking sure of our thesis—
If thinking at all.

It was aimed at the future,
The past we forgot,
The present was vague
Did it matter or not?

But now,
Have we any foundation?
If any,
It is pretty nearly upset.
However,
Let's get busy and prove not only
That we have one but that it is
The Best in the World.

So along with our sweating
Let's put up a song
As we knock out the Axis,
Help China along,
Make wings for our Victory,
Guns for our boys,
Save rubber and do it
With plenty of noise.

—E.M.T.R.

MARINE ENGINEERS AND NAVAL ARCHITECTS SOUGHT THROUGH LOWERED REQUIREMENTS

To speed its shipbuilding program for war, the federal government needs additional naval architects and marine engineers. The United States Civil Service Commission has modified requirements for these positions in order to meet demands from the Navy Department and the Maritime Commission.

Salaries for Naval Architects and Marine Engineers range from $2600 to $5600 a year. Most positions will be filled in the $2600 and $3200 grades, and requirements for these, as well as for the $3800 positions, have been lowered. There are no age limits.

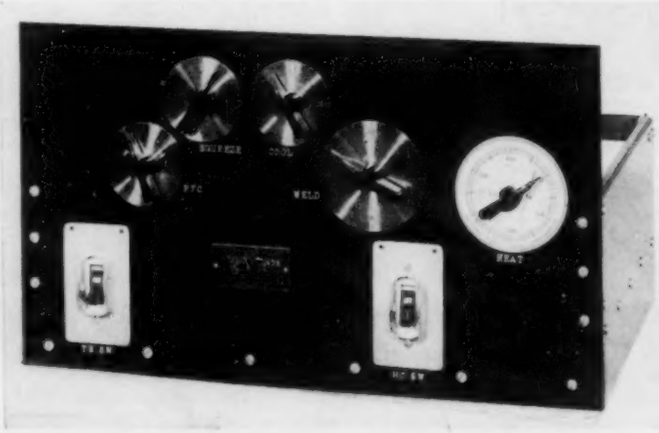
Applicants for all foregoing grades must either have completed a 4-year course in engineering or naval architecture at a recognized college, or had 4 years of comparable experience. In addition, for the $2600 naval architect positions, 1 year of professional naval architectural experience, or of engineering experience including at least 6 months of naval architectural experience, is required. For the $2600 marine engineering positions, 1 year of professional engineering experience including at least 6 months of marine engineering experience is necessary. Additional appropriate experience is required for the higher positions.

No experience is required for Junior Engineers in Naval Architecture or Marine Engineering, $2000 a year. A degree in naval architecture or marine engineering may qualify, as will a degree in engineering or architecture combined with 10 semester hours in naval architecture or marine engineering, or the equivalent in War Training courses.

Application blanks, obtainable at first- and second-class post offices, must be filed with the Civil Service Commission, Washington, D. C.

For ALCLAD SPOT WELDING—Use TRI-TROL

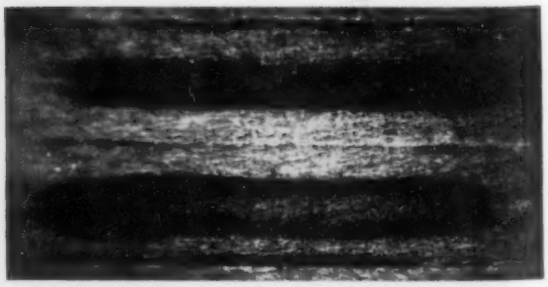
The COMPLETE WELD-CONTROL and SEQUENCE PANEL, with Automatic HY-LO Current Flow



Passes very high Weld Current for 1/2 cycle, followed by variable Tempered Heat for the balance of the Weld Interval.

Prevents Cracks — Makes Uniform Welds
Prevents Indentation — Makes a Ductile Joint

Penetration is Regulated by the Dials



Industry knows of the Heat Treatment of Steel, and how important the Cooling Process is. National just applied this idea to Aluminum Welding, and brought this treacherous metal under the Control of Tri-Trol dials. At the right, you observe how Tempered Heat is used to alter the extent of penetration, in 2 pieces of .016 Alclad sheet.

Both these welds were made in succession. High Current was not changed. Weld time was 2 cycles. Top weld with 40% Penetration, used Tempered Heat 40% off High Heat. Lower weld, with 50% Penetration, used 25% reduction.

NATIONAL TIME & SIGNAL CORPORATION

600 E. MILWAUKEE AVENUE — DETROIT, MICHIGAN

New Data on Spot Welding of Nickel, Monel *and* Inconel

Result of a two year research program at the Welding Laboratory of the Rensselaer Polytechnic Institute

Definite information on the spot welding of Nickel, Monel* and Inconel* was presented last October at the Annual Meeting, A.W.S., in Philadelphia. Reprints of this paper, by Wendell F. Hess† and Albert Muller‡, are now available.

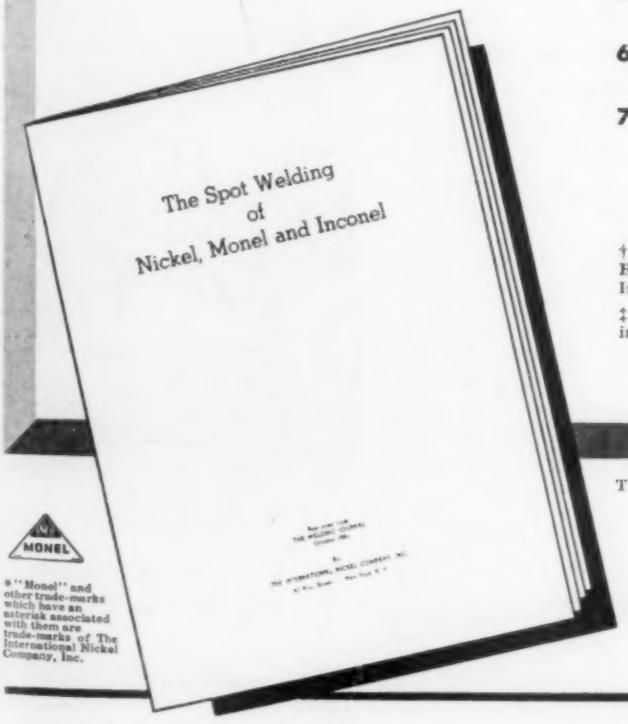
The results reported include data on:

1. Recommended welding conditions for producing sound spot welds in Nickel, Monel and Inconel sheet.
2. Strength of spot welds.
3. Recommended electrodes.
4. Control of energy input.
5. Limit of permissible distortion, and method of measuring it.
6. Load-distortion characteristic curve for single-spot lap-weld specimens.
7. A fast, efficient method for evaluating quality of spot welds made in shop.

For your copy of this paper please mail the coupon below

† Associate Professor of Metallurgical Engineering and Head of the Welding Laboratory, Rensselaer Polytechnic Institute, Troy, N. Y.

‡ Research Fellow, Department of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.



THE INTERNATIONAL NICKEL COMPANY, INC., 67 Wall Street, New York, N. Y.

Gentleman: Please mail ..... copies of your new bulletin, "Spot Welding of Nickel, Monel and Inconel" to:

Name..... *Title*.....

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W.J. 9-42

* "Monel" and other trade-marks which have an asterisk associated with them are trade-marks of The International Nickel Company, Inc.

TRAINING MEN NEEDED IN WELDING JOBS

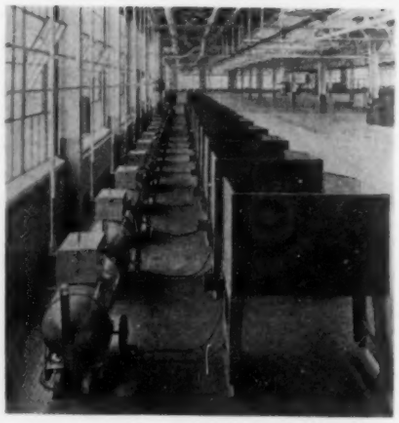
St. Paul, Minnesota.—Responding to the urgent need for arc welders in the construction of ships, planes, tanks and gun carriages, the Twin City branch of the Ford Motor Company has set up a score of welding booths, with complete equipment, and has already trained 200 men.

To augment its supply of welders, the Ford Motor plant here took applications for training from men who formerly worked on the assembly line, or who had other occupations less vital to America's war effort than welding. The training program was planned and initiated by H. C. Dorsey, the plant superintendent.

The training school, occupying a portion of the floor in one plant, is spotlessly clean. Beside each booth is one of the latest models of the portable arc-welding machines.

On eight-hour shifts, the booths are occupied by 20 men, who receive intensive training in flat welding. The school, according to Dorsey, is temporary, and as soon as a sufficient number of operators have been trained and are ready to go into production, the welding machines will be set up elsewhere in the Ford plant for actual production.

In the courses of study the Ford plant has arranged for evening meetings with the students and shop personnel. At these meetings, instructors, by means of slides and blackboard drawings, show the methods of producing different welded joints and explain the problems involved in each.



Photo, courtesy Lincoln Electric Co.

Students Being Trained as Welders in the Unique Setup at the Twin City Plant of the Ford Motor Company

WELDING ELECTRODE CONSERVATION

A new 14-page "fight waste" bulletin—"Make 3 do the work of 4"—has just been issued by Air Reduction Sales Co., 60 East 42nd St., New York, N. Y. The booklet, which consists of a series of shop posters, is designed to help arc-welding operators do more useful work with every electrode. Each poster—and there are six in all—illustrates a common wasteful practice, then shows the corresponding good practice and points out the ease and simplicity of doing the job the right way. Posters are bound securely into the booklet—yet are perforated and can be easily detached and tacked on shop bulletin boards.

Copies of this really helpful booklet may be had without obligation. Requests should be sent to the nearest Airco office or to the company's home office in New York.

SAFETY COUNCIL

Ned H. Dearborn, of New York City, today was named executive vice-president and managing director of the National Safety Council.

He succeeds W. H. Cameron, who is retiring after almost 30 years as managing director of the Council.

Mr. Dearborn's appointment was announced by Col. John Stilwell, president of the Council, following a meeting of the executive committee.

Since 1934, Mr. Dearborn has been dean of the division of general education of New York University, a post he now leaves.

In his new position he will actively direct the greatly expanded wartime program now being conducted by the National Safety Council as a result of a proclamation by President Roosevelt.

National

Carbide

IN THE RED DRUM

EFFICIENT

ECONOMICAL

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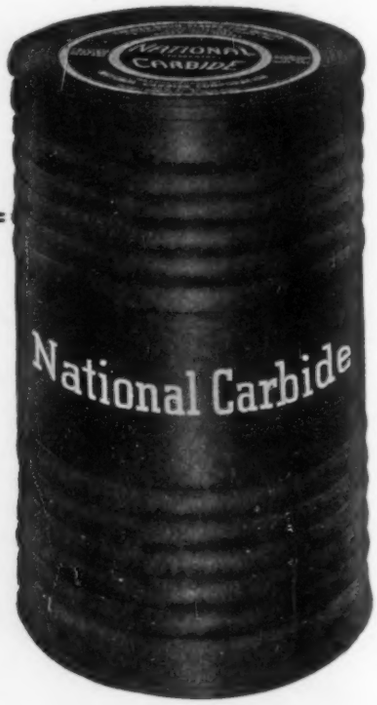
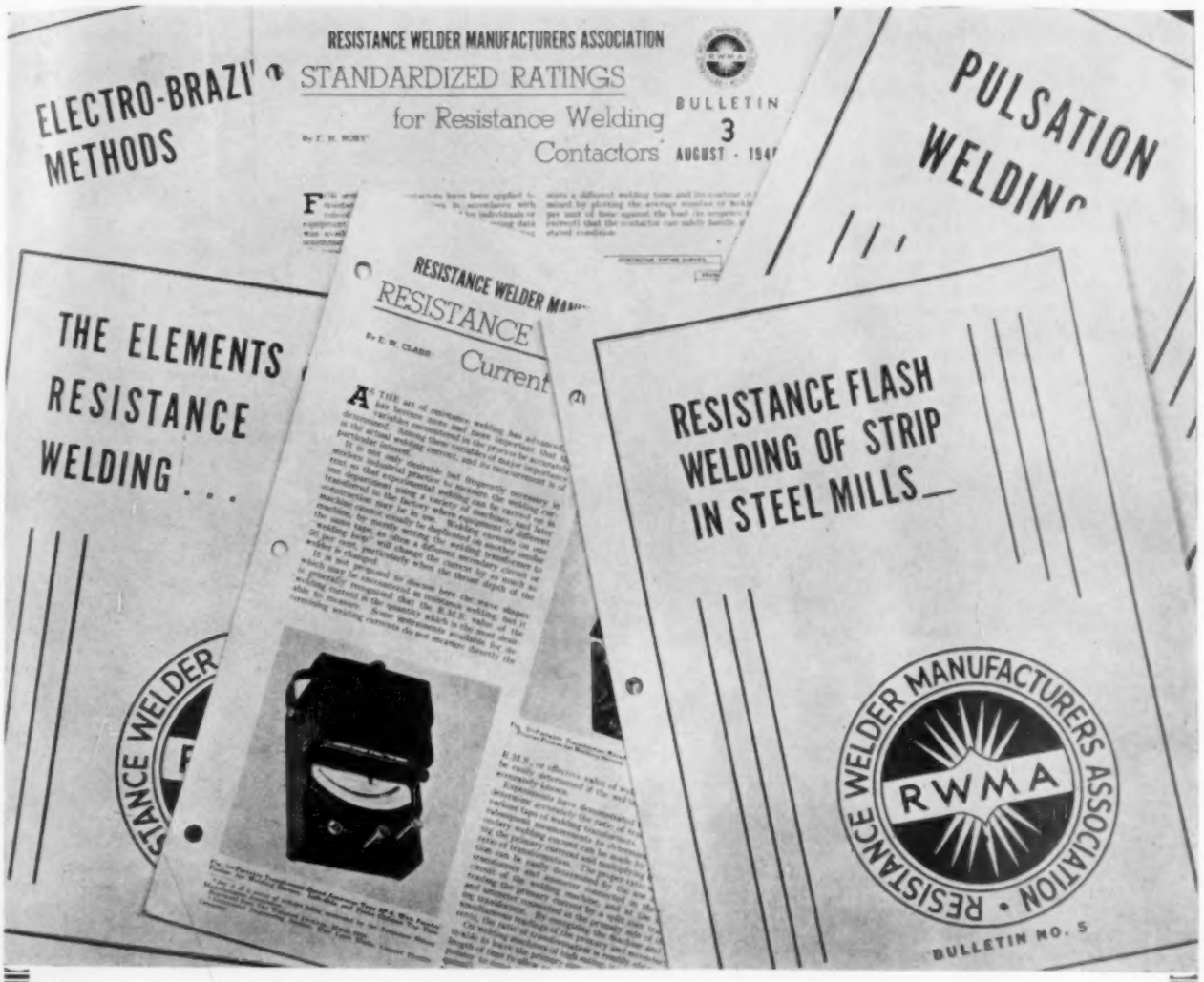


FOR WELDING and CUTTING

Use National Carbide in the Red Drum

60 E. 42nd St. NATIONAL CARBIDE CORPORATION New York, N. Y.



TECHNICAL LITERATURE ON RESISTANCE WELDING—

The Resistance Welder Manufacturers' Association publishes from time to time technical articles or reprints on resistance welding subjects of general interest. The Association invites anyone interested in the development of resistance welding operations to write in for these bulletins. Complete information on request.

RESISTANCE WELDER MANUFACTURERS' ASSOCIATION

505 ARCH STREET PHILADELPHIA, PA.

MEMBER COMPANIES

Eisler Engineering Company, Newark, N. J.
Expert Welding Machine Company, Detroit, Mich.
Federal Machine and Welder Company, Warren, Ohio
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City, Mich.
Progressive Welder Company, Detroit, Mich.
Swift Electric Welder Company, Detroit, Mich.
Taylor-Hall Welding Corporation, Worcester, Mass.
Taylor-Winfield Corporation, Warren, Ohio
Thomson-Gibb Electric Welding Co., Lynn, Mass.
Welding Machines Mfg. Company, Detroit, Mich.
Acme Electric Welder Company, Los Angeles, Calif.

ASSOCIATE MEMBER COMPANIES

S-M-S Corporation, Detroit, Mich.
Electroloy, Inc., New York, N. Y.
Welding Sales and Engineering Co., Detroit, Mich.
P. R. Mallory and Co., Indianapolis, Ind.

Necessary funds for this enlarged program—aimed at stopping accidents that are impeding production and delaying victory—now are being obtained from commerce and industry by the Council's War Production Fund to Conserve Manpower.

An initial appropriation of $250,000 from this fund will be made available to the Council for immediate development of this wartime safety program, Colonel Stilwell said. An additional $1,000,000 already pledged will be allocated within the next few months. A goal of $5,000,000 has been set to meet the minimum needs of the expanded program.

MACHINE SHOP YEARBOOK

A book entitled *The Machine Shop Yearbook and Production Engineers' Manual 1942* has just been published by Paul Elek Publications, Africa House, Kingsway, London, W.C.2. The editor is H. C. Town, M.I.Mech.E., M.I.P.E. There is also a foreword by Sir Alfred Herbert, K.B.E.

The book contains 558 pages, copiously illustrated. There is a section on Heat Treatment of Metals, Welding and Brazing. The price of the book is 25 shillings, plus postage of 9 pence.

NEW BUILDING CONSTRUCTION CONSERVES STEEL

Application of a diagrid construction technique made possible by recent developments in electric arc welding has cut steel requirements 30% in erecting a new laboratory at the Westinghouse East Springfield works. In addition maximum protection against destruction by bombing is provided.

To save the time and money that would have to be spent to move valuable experimental apparatus to another location, the new building framework was erected around the old laboratory.

In using the diagrid method, a series of diagonal steel beams has been crossed from one side of the framework to the other in two parallel sets. Intersections are welded together to give the diagrid the strength of one piece of steel rather than many individual pieces. The construction eliminates heavy lattice girders and trusses, and reduces the necessary thickness of steel beams.

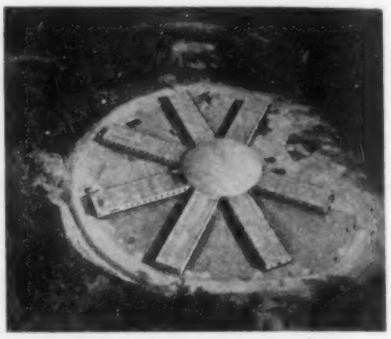
This Workman Is Welding One of the Joints of the Welded Structure. War Research Is Carried on Within an Old Frame Building Around Which the New Laboratory Is Being Erected

Additional advantage of the diagrid construction is that the steel framework of the roof is on the same plane as the ceiling itself, enabling the installation of tall machinery. Elimination of the steel maze customarily found in such a structure will also make for better ventilation and light distribution. A 40% reduction in the surface area of the steel will cut painting and maintenance costs and reduce corrosion and moisture condensation.

LAKE LOUISE HOTEL*

The most unique and interesting all-welded steel building ever built, according to the opinions of leading architects, is the Canadian Lake Louise Hotel. This welded steel hotel was built in the form of an eight-pointed star—with one ray cut away to allow for the front entrance. The walls, roof and dome were made from 12-gage mild steel plate which was prefabricated on the site into panel sections. Over 250 tons of steel were used for the panels and 60 tons of insulation were put into the walls and ceilings. This job, of course, was finished prior to the steel scarcity in the States and in Canada.

Each ray section of the hotel is 125 ft. in length, 32 ft. in width and 9 ft. 4 in. in height. The center dome is 100 ft. in diameter with no central supports. It consists of regular panel sections staggered in welded rows, a special jig, consisting of a center pole with swinging boom, was used to place the dome panels



and to support a platform for overhead welding on the inside of the dome.

A crew of 20 welders and 20 setup men constructed the building in six weeks. Roof and wall panels were constructed on the building site. A special jig, containing magnets, was used to hold the sheets apart while the cross braces for the panels were tack welded. Roof panels were 46 in. wide, 92 in. long and 18 in. deep. Wall panels were 46 in. wide, 92 in. long and 6 in. deep. Twelve hundred and seventy roof panel sections were used in the construction and 1125 wall panels.

Twelve and seven-tenths miles of weld were necessary to finish the hotel. Thirty thousand pounds of mild steel welding electrodes were used on the job. Twenty 200-amp. arc welders were in use on the site.

* This story was a prize winner in Hobart's Monthly Arc Welding News Contest. Photograph, courtesy Hobart Brothers Co.

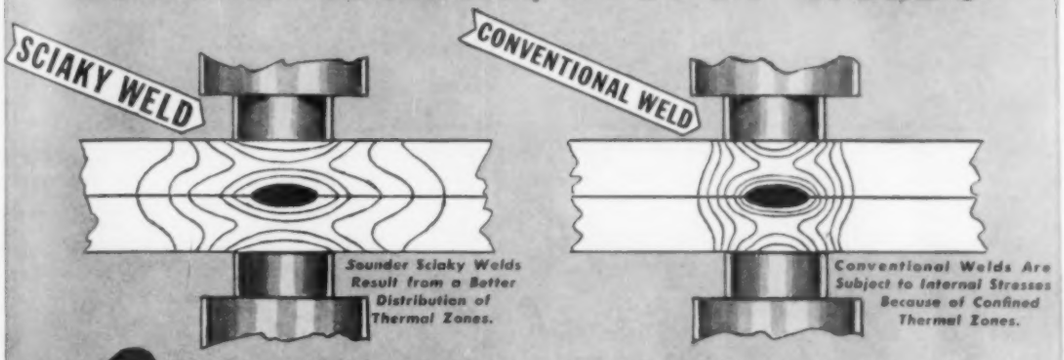
MALLORY STANDARDIZED WELDING ELECTRODES

SPEEDIER PRODUCTION
LESS DOWN TIME
BETTER WELDING
LOWER COST

The men who man high speed spot welding guns, single and multiple spot welders, seam welders and flash welders . . . rely on Mallory for long life electrodes! Write for your free copy of the factual Mallory Resistance Welding Data Book . . . today.

P. R. MALLORY & CO., Inc., INDIANAPOLIS, INDIANA • Cable Address — PELMALLO

WHY *Preheating* RESULTS IN BETTER ALUMINUM SPOT WELDS


SCIAKY WELD
CONVENTIONAL WELD
Sounder Sciaky Welds Result from a Better Distribution of Thermal Zones.
Conventional Welds Are Subject to Internal Stresses Because of Confined Thermal Zones.

3 *Important Advantages*

provided by this Exclusive Sciaky Feature

Aluminum has two characteristics unfavorable for the production of sound, uniform spot welds: (1) an extremely high thermal conductivity, and (2) an electrically resistant surface oxide. The Sciaky Welding Process compensates for these objectional factors by automatically preheating the metal around the spot to be welded.

Type PMCO25-16 Sciaky Electric Resistance Welder. Eighty spot welds per minute on two sheets of light alloy of .040" each. Welding capacity: From two thicknesses of .016" each in light alloys up to and including two thicknesses of .091".

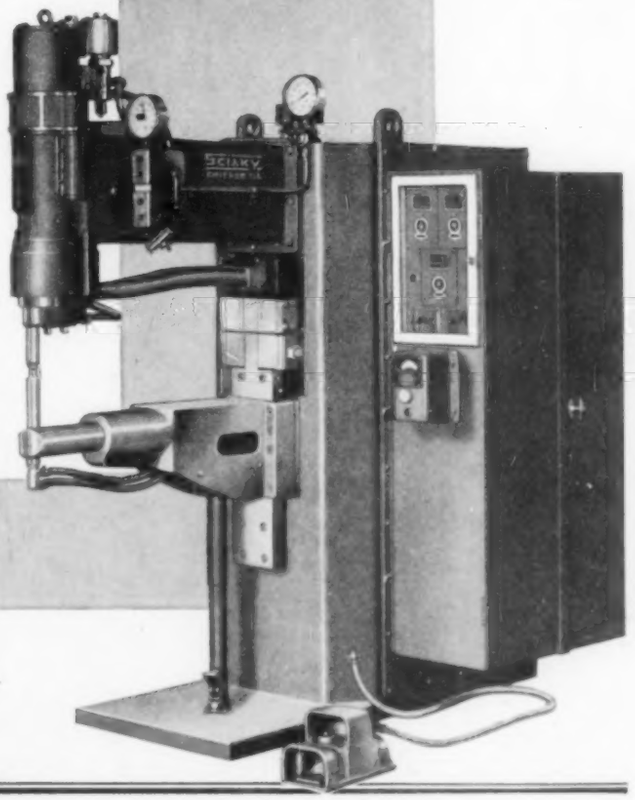
This Is What Preheating Does:

(A) **REDUCES STRESSES** which produce shrinkage cracks in the metal being welded. Preheating the area to be welded, and the adjacent metal as well, avoids too rapid cooling of the weld nugget.

(B) **REDUCES SURFACE OXIDES** not removed by chemical cleaning, thus leveling off the surface resistance to a low *constant* value, permitting precise control and uniform welds.

(C) **REDUCES ELECTRODE "PICK UP"** by lowering the surface contact resistance, thus enabling the production of more welds between tip cleanings.

PREHEATING is only one of many exclusive features of the Sciaky Welding Process. You are invited to submit your welding problem on your wartime products.



SCIAKY BROS.

Manufacturers of a complete line of D-C and A-C Electric Resistance Welding Machines

4915 West 67th Street, Chicago, Illinois

SCIAKY

*Pronounced See-ack-ee

The hotel contains 70 rooms in four of its wings; dormitory in each of two other wings; dining hall and kitchen in the seventh wing. The hotel's huge dome has a seating capacity of 1600 people.

All of the water pipes, steam pipes and sewer pipes were brazed together. Main feed lines were put around the lobby section with four feeder lines running down each side of the wing on the outside. These feeder lines were put into a box and insulated. Since these lines supplied hot and cold water, steam heat and sewerage, they had to be separated by insulation.

The floor was made from reinforced concrete 6 in. thick. Junior 6 in. I-beams were used on the outside of the concrete and also across the concrete for welding the wall panels to and for expansion joints.

Advantages of welded construction, according to John F. Dillon, Jr., welding engineer on the project, were:

1. Ease of construction.
2. Low initial cost.
3. Low maintenance costs.
4. Short construction time.
5. Fireproof, termite proof, lightning proof. Tight insulation made hotel cool in summer—warm in winter.

WELDING

Welding by James A. Moyer. Published by McGraw-Hill Book Company, Inc., New York, N. Y. 185 pages. Price $2.25. The object of this book is to describe in a general way the various modern methods of welding metals, particularly iron and steel. The book contains the following chapters: Welding with Gas Heat, Welding Torches, Pressure Gages and Regulators, Study of Oxyacetylene Flame, Oxyacetylene Welding Technique, Characteristics of Electric-Arc Welding, Sources of Current for Arc Welding, Electrodes and Holders, Welded Joints, Deposit of Metal, Metallurgy of Welding, Tests of Materials and Welds, Weldability of Metals, Flame and Electric Metal Cutting, Other Welding Methods, Welding Costs, Safety Equipment, Appendices on Trouble Shooting for Arc Welding, Table of Temperature Conversion and Welding Machine Parts Made by Powder Metallurgy.

SEVENTH EDITION LINCOLN WELDING HANDBOOK

Procedure Handbook of Arc Welding Design and Practice, seventh edition, published by The Lincoln Electric Company, Cleveland, Ohio; 1308 pages, 6 × 9 inches, 1810 illustrations, including photos and drawings; cover, semi-flexible simulated leather, gold embossed; price postpaid United States $1.50 per copy, elsewhere $2.00 per copy.

Greatly enlarged, the seventh edition of the *Procedure Handbook*, just published, takes on a new significance this year.

As pointed out in the preface to the seventh edition of the Handbook, which has gone through 23 printings, the United States started out with a handicap in the armament race with the Axis, but the odds are being met by the widespread application of welded construction to the implements of war.

Authors of the book have made every effort to provide as much complete and up-to-date information as possible to help the men in the shops, shipyards, airplane factories, ordnance plants and arsenals produce to the fullest extent.

The book explains more fully than ever before the various methods and techniques used in welding, with a view to speeding up welding design and engineering and to make it easier for the thousands of men in training to learn the essentials of welding in the shortest possible time.

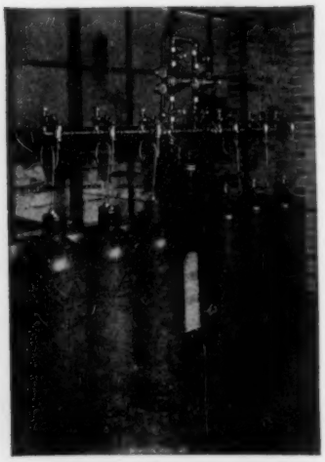
Illustrated more exhaustively and more clearly than ever before is the chapter on "Typical Applications of Arc Welding." Large numbers of these new applications have been developed during the past year in the many fields of war production.

ANNOUNCING ROBBERSON STEEL COMPANY

J. B. Klein Iron & Foundry Company was first established in 1909 by Mr. J. B. Klein, deceased in 1925.

The management and personnel, some of whom have employment records ranging up to 30 years, are grateful to and proud of its many customers and friends.

For SAFETY *SPEED* ECONOMY



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FREE TO WELDING ENGINEERS!

NEW Oakite Digest Tells How to Spot Weld Aluminum Faster and Get Stronger Welds!

Are you a process engineer, metallurgist, welding supervisor or foreman interested in speeding production, securing stronger, more uniform welds in spot welding aluminum alloys? If so, you will want this NEW 13-page Digest on surface preparation. A valuable digest of charts, diagrams and other data, it describes improved Oakite process now being successfully used by leading aircraft plants and others for safely, speedily removing oil, grease, dirt, identification paint and oxide films. Available only to executives requesting it on company letterhead.

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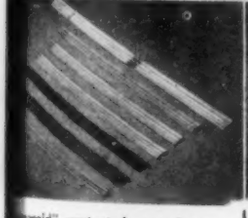
MATERIALS METHODS SERVICE FOR EVERY CLEANING REQUIREMENT

WELDING..

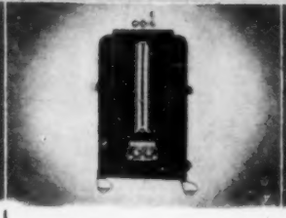
Tanks . . . Guns . . . Planes — and even the Ships used to transport them — are getting to our fighting fronts faster and in greater number because of welding.

Hollup Corporation, a division of National Cylinder Gas Company, is doing all it can in the 24 hours of each day to speed its output of rods and electrodes, A.C. and D.C. welding machines, "Shield-o-matic" welding apparatus, and the new Stud Welding System.

HOLLUP *products and services are helping speed war production*



...weld" protected arc elec-...s, in many types and sizes, ...the best results for any job.



Electric welders for A.C. or D.C. operation are available in a complete range of sizes to meet any requirement.

"Shield-o-matic"—fully automatic shielded-arc welding process which meets all code requirements.

Stud welding system for production end-welding of steel sections to metal surfaces.

HOLLUP products may help speed your output . . . *Write for literature, specifying equipment in which you are interested.*

HOLLUP CORPORATION

DIVISION OF

NATIONAL CYLINDER GAS COMPANY

205 W. WACKER DRIVE — *Offices in Principal Cities* — CHICAGO, ILLINOIS

ELECTRODE MANUFACTURING PLANTS—CHICAGO, ILL., STOCKTON, CAL. AND TORONTO, CANADA.

In the Robberson Steel Company, successor to J. B. Klein Iron & Foundry Co., the management, personnel and capital structure remain unchanged.

Robberson Steel Company, its staff of experienced executives and all of its personnel, will continue to efficiently serve the construction industry.

SOLENOID SPOOL SILVER BRAZED TO PREVENT WARPAGE

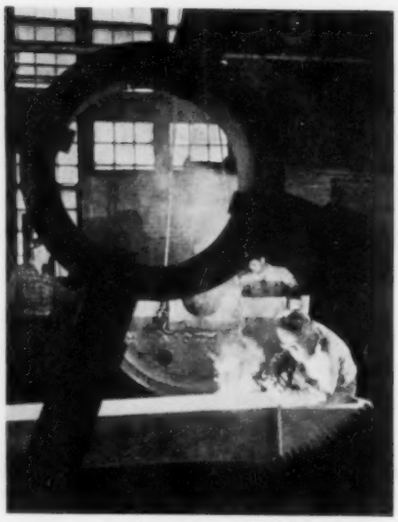
As big guns swing into firing position and throw tons of metal at far away objectives, both guns and turrets are controlled by mechanisms, an important part of which is a 2-in. solenoid core wound on a light-weight brass spool shown in the photo.

Photo, courtesy Handy & Harman

The brass end-piece of this spool is fitted on a brass tube and joined permanently to it by a low-temperature silver brazing alloy. The previous method, using a high-temperature base metal brazing alloy considerably distorted the spool. Distortion is now eliminated because the joint is made at the low temperature of 1175° F., the brazing temperature of the silver alloy. The joint, made easily and rapidly, is stronger than the brass itself.

WELDING HELPS SPEED PRODUCTION

Welding has played a big part in General Electric's fast accelerating production for war—a production which saw turned



Photo, courtesy General Electric Co.

out in the first four months of this year as much as was produced in all of 1941, which itself was a year of greatly increased production. Looking through a large combination stator frame and bearing bracket, itself welded at an eastern G-E plant, we see a welder using alternating current to make a weld on a bearing bracket arm for a large turbine.

HELP PUT EMPTY CYLINDERS TO WORK

Production requirements today are such that there is an increased demand for oxygen and acetylene. This demand can be met if empty cylinders are returned promptly and if cylinder stocks in the hands of users of oxyacetylene welding and cutting are maintained at a minimum.

Cylinders must be kept moving. They must not be permitted to stand idle, either full or empty. The cylinder supply, now the most important factor in the distribution of compressed oxygen and dissolved acetylene, is still deemed adequate to keep these gases continually and readily available to essential users if all will cooperate in speeding up turnover rates.

Also, refrain from ordering more oxygen or acetylene than is required for immediate needs. Many shops allot not more than three oxygen and three acetylene cylinders to every two welding or cutting outfits in active service. This plan permits a 50% reserve.

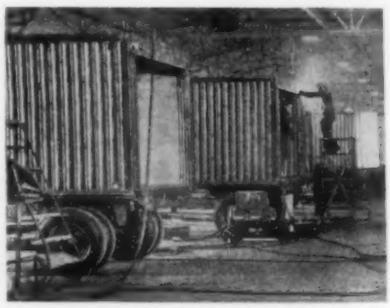
This appeal is made just as much to small shops, using two or three cylinders a month, as it is to large plants using up to one hundred or more cylinders a month. For every day a cylinder is empty and idle is a day lost out of its productive life regardless of the size of the shop.

FLUXINE DISTRIBUTOR

Krembs & Co., Chicago, has appointed Universal Power Corporation, Cleveland, Ohio, as its stocking distributor of Fluxine fluxes and Kop-R-Arc welding rods and other Krembs products in the Cleveland trade area, embracing all of northern Ohio, according to A. Leslie Pfeil, president of Universal Power Corporation. Mr. Pfeil states that his company is making arrangements for dealers throughout the area to be serviced from Cleveland stocks.

ARC-WELDED TRAILER TRUCK BODIES

Trailer truck bodies and chasses made by the Trailer Company of America, Cincinnati, Ohio, are fabricated by arc welding for fast, economical assembly and light weight. The advantages accruing from arc welding do not stop here, however, since these trailers can be easily repaired, the damage section being cut out of the body, straightened out, and then rewelded into place.



Photo, courtesy General Electric Co.

Buy "Proven Fluxes" with Years of Guaranteed Satisfaction behind them
The Trade-Name is "ANTI-BORAX"

Ask for Them *Unequalled for Quality*

A Flux for every metal: Cast Iron Welding Flux No. 1; Brazing Flux No. 2; Braz-Cast Flux No. 4, for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; "Anti-Borax" Tinning Compound No. 11.

ANTI-BORAX COMPOUND COMPANY
Fort Wayne, Indiana

You'll do it better with
SHAWINIGAN CARBIDE

SHAWINIGAN
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EMPIRE STATE BLDG., NEW YORK

Official U. S. Navy Photograph

★ When an experienced welder goes to work for the Navy, they don't just turn him loose on the job. Even the best of new men are trained with great care to work to Navy requirements—and are checked by experts.

Certainly, with the material and delivery situation as it is, it is good business to see that all industrial welding procedure is carefully checked—that electrodes of the proper size, leaning toward larger sizes, are used—that no electrodes are wasted—that no excess is deposited in the weld.

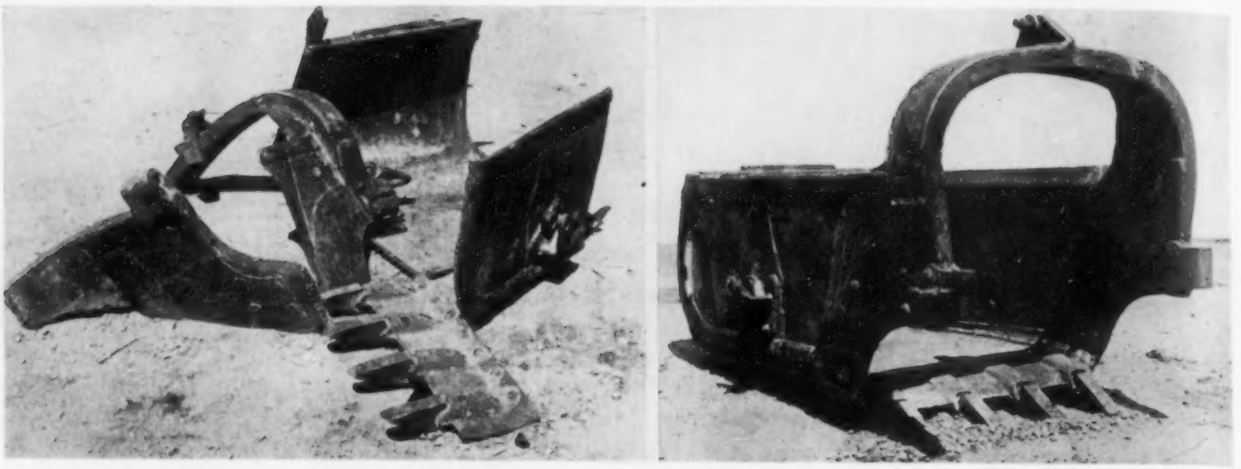
WELDING STAINLESS? You will find a great deal of practical information on Stainless Steel and Stainless Steel Welding procedure in this 9x12 booklet. Get a copy from your local **PAGE** distributor.

PAGE WELDING ELECTRODES

PAGE STEEL AND WIRE DIVISION · Monessen, Pa., Atlanta, Chicago, New York, Pittsburgh, San Francisco

AMERICAN CHAIN & CABLE COMPANY, Inc.

BRIDGEPORT, CONNECTICUT



Photo, courtesy Hobart Bros.

WELDING FOOLS UNPATRIOTIC THIEVES

Even the unpatriotic action of scrap thieves could not interrupt the construction of a military airport in North Carolina when an arc welder was within easy call of the contractor. Thieves cut the drag line bucket, shown in the picture above, into six pieces with an acetylene torch and sold the pieces for scrap. Alert police authorities, however, spotted the pieces on a freight car enroute to the mills and shipped the parts back to the airport contractor.

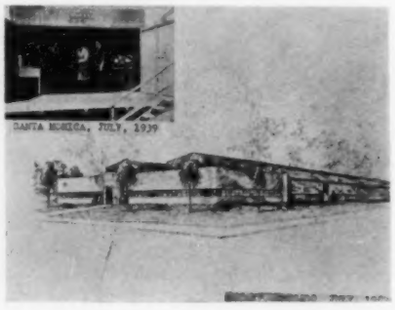
Emmett C. Aldredge, job welder from Dunn, N. C., was called to the construction site to make repairs. This bucket, constructed from $^1/_4$ and $^1/_2$-in. mild steel with a manganese wearing lip, could be repaired by welding easily.

First, all parts were "Veed" with an acetylene torch. Then all parts were replaced to their original position by welding with $^5/_{16}$ and $^1/_4$-in. electrodes. A new drag line bucket of this size would have cost $365 and would have required weeks for delivery. The repair job by welding required only 10 hr. and cost $90. Welding machine used on the job was a standard 330-amp. arc welder.

DEMAND FOR SCIAKY WELDERS NECESSITATES NEW FACTORY

The steady growth of Sciaky Bros. makers of precision-built electric resistance welding machines, is but another shining example of America's immediate recognition of advanced methods.

The Sciaky process, which embodies the principle of stored-energy and the variable-pressure cycle as well as other features of Sciaky manufacture, was first presented to Army and Navy officials and Douglas Aircraft Company on the West Coast and resulted in the purchase of a welder by Douglas for test operation,



attracted by the remarkable power cost savings resulting from the application of the stored-energy principle. The Southern California Edison Power Company, who were becoming alarmed over the ever-increasing demands for electric power required to operate the conventional type of welder, built a shed for a demonstration of the Sciaky welding process at Santa Monica, Calif.

As the advantages of the Sciaky process became known in aircraft manufacturing circles, the demand for these new-type welding machines grew apace. In order to keep pace with this unprecedented program, plans were drafted for a new factory with ample space for enlarged operation and the broadening of the line to include machines for all weldable metals.

Sciaky Bros. moved into their new building located at 4915 West 67th St., Chicago, near the Municipal Airport, July 3rd, just a little over two years from the sale of the first machine.

THE HOBART GROUP

Here is a 20-page booklet which editorially and pictorially explains the products, manufacturing and engineering facilities, and wartime activities of the companies making up the Hobart Group of factories.

ELECTROLOY ALLOYS for RESISTANCE WELDING ELECTRODES and DIES

Spot
Seam
Butt
Flash
Projection

ELECTROLOY ALLOYS were developed specifically for the resistance welding industry. ELECTROLOY ALLOYS cover the full range of physical properties necessary to the manufacturers and users of resistance welding equipment.

Our engineers will be glad to make recommendations for your special electrodes. Submit samples or specifications.

Catalog and prices available on request.

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FREE 36 PAGE BOOK Write Today

Castolin EUTECTIC LOW TEMPERATURE WELDING

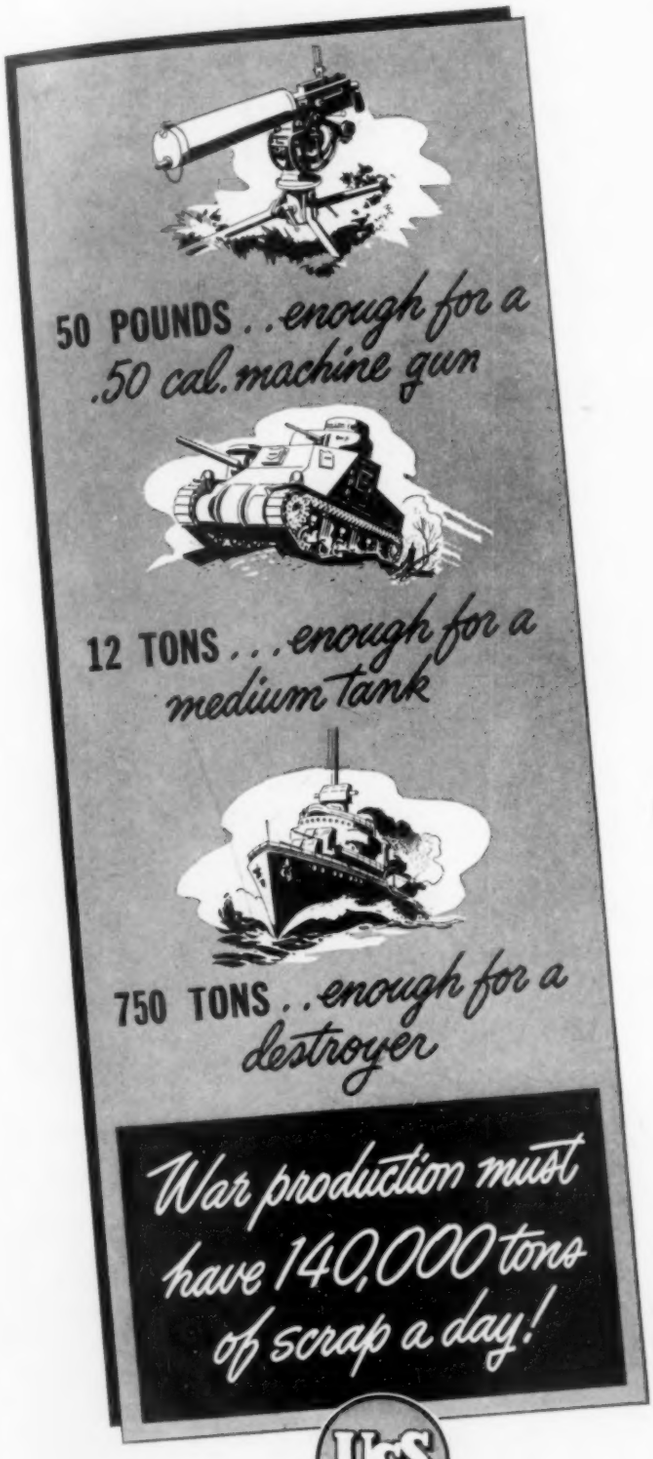
This new low temperature method has revolutionized welding. It binds without melting the base metal. This means high strength . . . matching color. It means less stresses . . . less warping . . . less preheating.

Try this modern welding method in your shop. The results will amaze you.

Welds: Cast Iron, Iron, Nickel, Steel, Aluminum, Bronze, Copper, Brass, Magnesium, etc.

EUTECTIC WELDING ALLOYS Inc. • 40 WORTH STREET NEW YORK, N. Y.

How much SCRAP can you mobilize every week?


50 POUNDS . . enough for a .50 cal. machine gun
12 TONS . . . enough for a medium tank
750 TONS . . enough for a destroyer
War production must have 140,000 tons of scrap a day!
USS

THE plain fact is—we can't win this war without plenty of steel. But if we are to have plenty, all factories, mills, shops, mines and other units of American industry must organize at once to turn in every available pound of scrap metal—and keep on turning it in regularly. At least six million tons more scrap must be collected than last year!

Where is this "extra" scrap?

It is certain that vast quantities of precious iron and steel lie idle in unsuspected hiding places throughout the country. Part of it may be on your premises. The usual methods of collection will not release enough to meet present demands. It will take special diligence on the part of management and workers alike to put the 1942 Scrap Drive over the top. To check the efficiency of your salvage methods, see if you are turning in all three of these classes of scrap:

"BREAD-AND-BUTTER" SCRAP—The kind most plants sell regularly — filings, shavings, stampings, rejects — metal scrap created in the process of manufacture or construction.

DORMANT SCRAP—Unused or abandoned equipment, broken or worn-out machine parts, old boilers, moulds, dies, pipe, valves, electrical equipment, engines, trucks, etc.—the "junk" that accumulates but often misses routine scrap collection.

"RAINY-DAY" SCRAP—The hardest of all to part with. Includes obsolete machinery, unused metal buildings, stacks, outdated tools, fixtures, patterns, stocks, etc.—idle now because they're being saved for possible use in some indefinite future emergency. The emergency is here! This metal should be scrapped, unless it can be reconditioned and put to work now.

If you haven't already, we suggest you organize your own scrap drive. Your local Industrial Salvage Committee will help you plan a forceful program. Put some one individual in charge of salvage in all departments of your business, and give him authority to act. Promote the drive to your employees with posters and prizes. Emphasize speed and continuous effort. Make them all "scrap conscious." If you need more information, contact the Bureau of Industrial Conservation, War Production Board, Washington, D. C.

YOUR SCRAP IS WORTH ITS WEIGHT IN VICTORY

★ ★ ★

AMERICAN STEEL & WIRE COMPANY, *Cleveland, Chicago and New York* · CARNEGIE-ILLINOIS STEEL CORPORATION, *Pittsburgh and Chicago* · COLUMBIA STEEL COMPANY, *San Francisco* · NATIONAL TUBE COMPANY, *Pittsburgh* · TENNESSEE COAL, IRON & RAILROAD COMPANY, *Birmingham*

UNITED STATES STEEL

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

NEW CRATER FILLER

A new crater filler has been announced by the General Electric Company for use with the G-E Strikeasy arc welder. The crater filler—a foot accelerator for welders—is designed to provide the very close auxiliary control of heat required in welding thin material, such as aircraft tubing, and to permit tapering off of the welding current at the end of a bead in order to fill the crater which is otherwise left. Unfilled craters have sometimes proved to be the source of cracks which are harmful to the strength of a weld. Properly filled craters provide full strength at the end of a weld bead.

The crater filler is essentially a combination of a foot-operated rheostat for reducing the current and a field forcing switch for providing a hot start or an increase in welding current when required. It is not intended to replace the function of the control on the Strikeasy, but is used to increase or decrease the heat setting to accommodate abnormal conditions at the beginning or end of a weld, or during a weld. Normal welding heats should be adjusted in the usual way.

The crater filler is particularly helpful when working with thin material where normal welding heats are low, as conditions frequently arise where normal welding heats are insufficient. At the start of a weld the electrode and base material are cold and fusion might be poor, with consequent pile-up of the deposited metal. A similar circumstance arises where the section to be welded suddenly becomes thicker, or when it is necessary to weld into or across a previously deposited bead.

In either of these circumstances, the crater filler gives adequate fusion when needed. The increased current is instantly available and the return to normal heat is instantaneous.

At the time of breaking the arc, the crater filler permits either a rapid or a slow decrease in current down to the point where the arc is extinguished. This assists the operator in mastering the technique of finishing a bead without a crater, because he can suit the rate of fading of the current to the conditions in that particular weld.

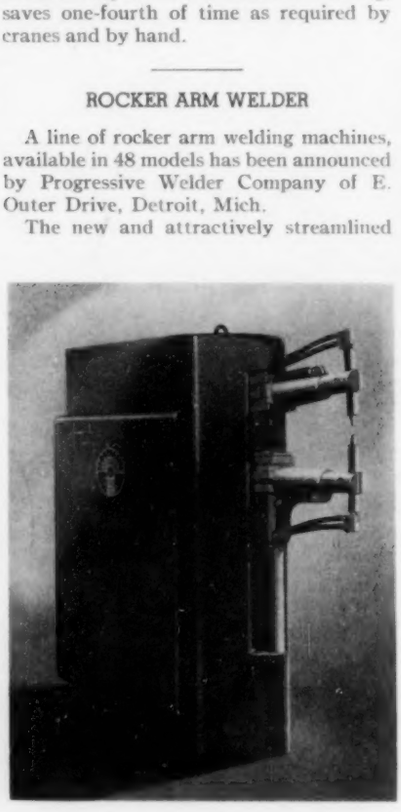
WELDING MARINE COUPLINGS

Making the fillet weld between the center plate and the outside rim on this marine electric coupling developed by Westinghouse to replace mechanical flexible couplings. Diesel engine torque and the pulsation is eliminated by the transmission of power from an energized field to rotor rather than by the contact of mechanical parts. Smooth maneuvering of ship is accomplished by the energizing or de-energizing of the desired couplings. The electrically operated positioner which turns the assembly while the welder is working, saves one-fourth of time as required by cranes and by hand.

ROCKER ARM WELDER

A line of rocker arm welding machines, available in 48 models has been announced by Progressive Welder Company of E. Outer Drive, Detroit, Mich.

The new and attractively streamlined rocker arm welders are available in four capacities with three types of drive and a full range of throat depths from 12 to 36 in. Standard capacities are 20, 30, 40 and 50 kva., and 50/60 cycle supply with other frequencies available at slightly higher cost.



To meet a wide range of requirements these machines are available for foot, air or motor operation. In the lowest-cost foot-operated type, the pressure to bring the electrodes together is obtained through pressure on a foot pedal connected to the rocker arm by a system of mechanical links. A limit switch to initiate operation of the contactor at proper pressure, is mounted on the overtravel spring.

A single-acting cylinder with piston rod connected to the rocker arm provides the pressure for the air-operated types, with a pressure regulator as standard equipment and spring pressure returning the points after completion of weld.

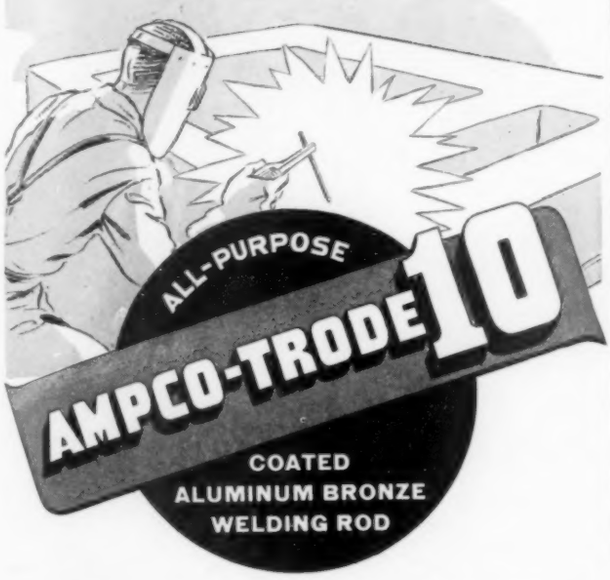
HOW TO REDUCE INDUSTRIAL EYE ACCIDENTS

Southbridge, Mass.—To drive home to war workers the importance of eye protection, Earl Davis wears an eye-patch bearing the grim message: "MY EYE WAS HERE. I should have worn safety goggles." The eye-patch was designed by the American Optical Company for safety directors to pass out to workers to give them an idea how it feels to have only one eye. This forceful reminder is expected to help reduce eye accidents which have increased sharply because of stepped-up war production, employment of new workers, inadequate supervision of this labor and carelessness in safety precautions on the part of workers.

HEATING UNIT FOR FIELD WELDING

The preheating and stress relieving of field welds in pressure piping have been brought to an exacting science through the development of flexible, electric resistance heating units with automatic temperature and heating cycle control by H. O. Swoboda, Inc., New Brighton, Pa.

When PREHEATING is DIFFICULT – use



Ampco-Trode 10 coated bronze electrode is unequaled for arc welding the copper-zinc alloys, particularly manganese bronze, and possesses special merit when the sections to be welded are very heavy and preheating for gas welding is difficult.

This welding rod has high strength, and its "hot-ductility," or lack of hot-shortness, is of great importance. It is particularly suitable for joining dissimilar metals by arc welding and it "arc-brazes" mild steel readily.

Made in seven grades, $\frac{1}{8}$" to $\frac{1}{2}$". May be used for metallic arc, carbon arc, or oxy-acetylene welding.

The Ampco line of coated bronze welding rods includes six other grades of Ampco-Trode; a high strength series with controlled hardness, well suited for overlaying steel and cast iron to form bearing surfaces.

Detailed information regarding Ampco-Trode welding rods sent on request.

AMPCO METAL, INC.
Department WJ-9 Milwaukee, Wisconsin

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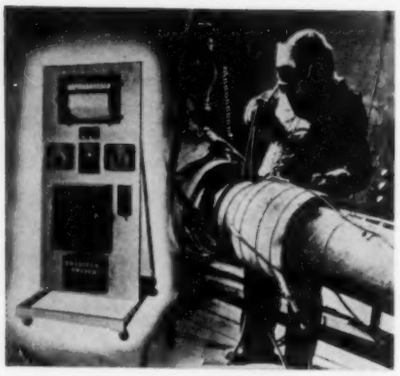


The heating units are a wrap-around type consisting of resistance wire sheathed in refractory insulation. Two of these units are wrapped about the pipe, one on each side of the joint, for preheating. After the weld has been made, a third unit is wrapped directly over the weld to create a uniform temperature sufficient for stress relieving over the entire joint including distance in excess of six times the pipe wall thickness at each side of the joint. Heat radiation is held to a minimum by a wrapping of asbestos or other similar heat insulation.

Of primary interest is the automatic control panel which, by the means of thermocouples, records and controls the individual point temperatures. The thermocouples are attached to each side of the pipe joint and directly to the weld. Direct connection between the temperature controlling instrument and each heating unit, through a magnetic contactor, regulates the energy input and assures uniform heating.

FLAME JIG SAW SPLITS CHANNELS

U-shaped channels are being split in half to provide stiffeners for structural use. The 33-ft. channels are loaded two at a time onto a special jig and clamped into place. Two oxyacetylene cutting machines are employed, riding a track in the center of the jig. Each blowpipe is mounted on a floating mechanism the bottom of which rides along a templet, thus automatically producing the zigzag line of cut in the base of the channel. This design of cut is selected because it results in a saving of weight and steel while the necessary strength to the beam is maintained. The two cutting machines, splitting two channels simultaneously, travel at a constant speed of 16 in. per minute.

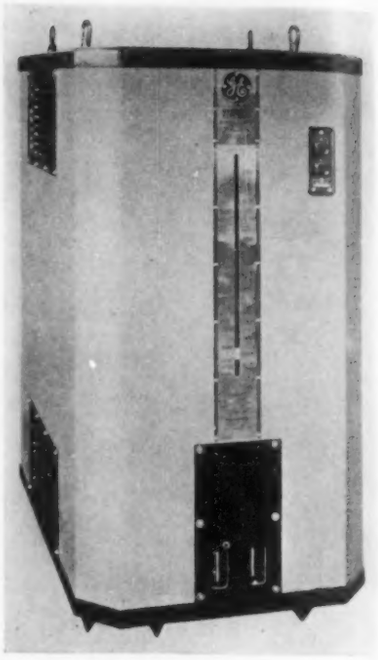
WELDING TRANSFORMERS FOR UNIONMELT WELDING

A new line of heavy-duty alternating-current welding transformers especially designed for Unionmelt welding has been announced by the General Electric Company. The welders are available in 750- and 1000-amp. sizes (NEMA) for 220-, 440- and 550-volt power.

Features of the line are built-in capacitors and built-in primary control. The capacitors are valuable for improving voltage regulation of the power feeders, thus aiding uniform welding. The built-in primary control not only simplifies wiring, but is advantageous in portable installations because of its compactness. It includes a disconnecting switch and auxiliary transformer to furnish power for operation of Unionmelt auxiliaries.

Motor-operated, remote adjustment of the welding current permits an operator to make current adjustments without leaving the work. The equipment's integral reactance design permits full output to be obtained without the use of high or multiple open-circuit taps.

Fan cooling conserves vital materials and space. Ample ventilation and the arrangement of ducts permit two welders to be mounted side by side without the need for extra space between them for ventilating air.



The current output of each welding transformer is indicated by a large, accurately calibrated scale on the front of the case. Inorganic (Class B) insulation is used throughout.

NEW SUSTAINING MEMBER

Allis-Chalmers Manufacturing Company, Milwaukee, Wisc., manufacturers of the WELD-O-TRON,—D.C. precision, low-current electronic arc welder for metals as thin as 28 gage at currents as low as 5 amp., such metals covering all weldable materials and alloys. Also a complete new line of heavyduty industrial A.C. welding equipment. Other lines include a variety of 1600 products representing complete lines in the electrical and heavy industrial fields.

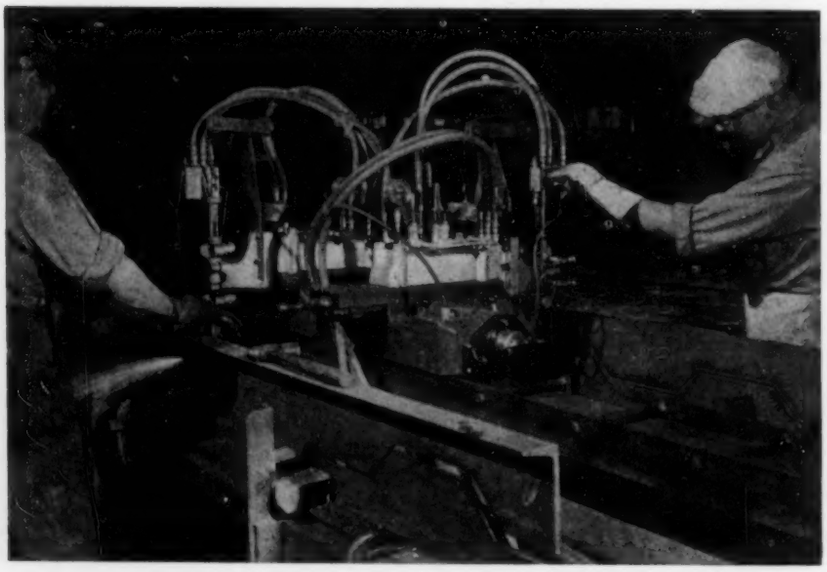
NON-FERROUS METALS ECONOMISTS

The U. S. Civil Service Commission is seeking well-qualified persons with experience in non-ferrous metals and their products.

The positions pay from $2600 to $6500 a year, and appointees should have a college education with a major in economics, and responsible experience or research work in the manufacture or distribution of non-ferrous metals and their products.

They will conduct investigations, analyze price and cost data, negotiate with particular groups to set up reasonable price schedules and rationing controls, and evaluate the results achieved.

Persons interested should write to U. S. Civil Service Commission, Washington, D. C., for application blanks—Form 4006-ABCD.



WELDING HANDBOOK

Prepared by 250 of the leading welding experts of the U. S. A.

Worlds's greatest source of authentic, concise, authoritative welding information.

Completely revised and enlarged.

For a short time no restriction will be placed as to the number of copies which may be purchased by an individual Member or Company as the Society feels it essential to make this book available promptly to all workers on War projects.

Sustaining Members and Members of the A. W. S. have received a free copy of the book; Associate Members and Operating Members will be able to purchase their first copy at $4.00. Extra copies can be purchased by all members from a supply reserved for this purpose at $5.00. Non-members $6.00 in the U. S. A.

1600 PAGES
1942 EDITION

List of New Members

July 1 to July 31, 1942

BOSTON

Shaw, John E. (C), Bethlehem-Hingham Shipyard, Inc., Hingham, Mass.
Wood, Thomas A. S. (B), Allis-Chalmers Mfg. Co., 1344 Hyde Park Ave., Boston, Mass.

CANADA

Atkinson, Kenneth (B), B. C. Welding Sales & Equip. Co., Armstrong, B. C., Canada.
Holland, Leonard (C), 231 Bay St., N., Hamilton, Ont., Canada.

CANAL ZONE

Walker, Ray L. (C), Box 337, Balboa Hts., Canal Zone.

CANTON

Daughenbaugh, C. J. (C), 524 Pike Ave., S. W., Massillon, Ohio.

CHICAGO

Blackford, J. F. (D), 322 N. Water St. Thornton, Ill.
Happel, Raymond (C), Handy & Harman, 20 N. Wacker Dr., Chicago, Ill.
Lindberg, S. R. (C), Mechanical Industries Tech. Inst., 515 S. Western Ave., Chicago, Ill.
Plaskon, John (C), Metal & Thermit Corp., 7300 S. Chicago Ave., Chicago, Ill.

CINCINNATI

Jenkins, Wm. (B), Tri-State Welding School, 110 Washington Ave., Lockland, Ohio.

CLEVELAND

Benjamin, Earl (B), 3981 W. 140th St., Cleveland, Ohio.
Butler, Spencer W. (B), 2460 Overlook Rd., Cleveland Hts., Ohio.
Portz, Arthur G. (C), 3404 W. 151st St., Cleveland, Ohio.
Schreck, Paul F. (B), 1755 Chapman Ave., E. Cleveland, Ohio.

COLUMBUS

Bates, Earl, Earl Bates Welding Service, 616 N. 9th St., Cambridge, Ohio.
West, W. W. (B), Home Welding Co., 114 S. Washington St., Springfield, Ohio.

DETROIT

Martin, George B. (C), Kilpatrick & Martin, 2832 E. Grand Blvd., Detroit, Mich.
Schriner, Ted (C), 16 Brighton, Highland Park, Mich.
Wheeler, Neil E. (C), 100 Miami Ave., Apt. A-1, Pontiac, Mich.

GEORGIA

Hunt, D. B. (B), 484 Brentwood Dr., N. E., Atlanta, Ga.

HAWAII

Crippen, Norris C. (C), 2400 N. King St., House 69 B, Honolulu, T. H.

LOS ANGELES

Blackshaw, Joseph T. (D), 2410 Howland Dr., Temple City, Calif.
Comer, Volney M. (D), Box 291, Tustin, Calif.
Evanko, Michael B. (C), 6519 S. Van Ness Ave., Los Angeles, Calif.
Ostranik, R. C. (D), 617 E. 76th Pl., Los Angeles, Calif.

LOUISIANA

Bramblett, T. L. (B), 902 Jackson Rd., Baton Rouge, La.
Stilwell, Chas. O. (B), Wm. D. Seymour Co., 1133 Magazine St., New Orleans, La.

MARYLAND

Lacy, Charles E. (B), 405 E. Oliver St., Baltimore, Md.
Linnert, George E. (B), Rustless Iron & Steel Corp., Met. Lab., 3400 E. Chase St., Baltimore, Md.
Schaufus, Henry S. (B), 807 Evesham Ave., Baltimore, Md.

MILWAUKEE

Ove, Val W. (C), 647 W. Virginia St., Room 205, Milwaukee, Wisc.
Smith, Charles S. (C), Hotel Underwood, Wauwatosa, Wisc.

NEW YORK

Adams, Richard L. (D), 228 Bergen St., Brooklyn, N. Y.
Babulya, Alexander W. (D), 48 E. Kingsbridge Rd., Bronx, N. Y.
Burnes, Ralph (D), 1611—42nd St., Brooklyn, N. Y.
Evers, John H. (D), 350 W. 85th St., New York, N. Y.
Ferguson, James, Jr. (C), 117 Ireland Pl., Amityville, N. Y.
Gellak, Harry G. (C), 170 Prospect Pl., Brooklyn, N. Y.
Guida, Stephen (D), 414 E. 16th St., New York, N. Y.
Hardesty, Shortridge (B), 101 Park Ave., New York, N. Y.
Jones, William J. (C), 934 N. 3rd St., Camden, N. J.

NORTHERN NEW JERSEY

DeJager, Henry (D), 249 Valley Rd., Clifton, N. J.
Jenal, Alfred (D), 48—63rd St., West New York, N. J.
Norton, Edward M. (B), 573 Bound Brook Rd., Dunellen, N. J.
Parker, Charles (D), 9 Miller St., Newark, N. J.
Ramberg, Gerhard B. (D), Wood Ave., Fords, N. J.
Smith, Murphy (D), 7 High St., Butler, N. J.

NORTHERN NEW YORK

Chotkowski, Z. F. (D), 15 Wagner Ave., Schenectady, N. Y.
Dominick, Nicholas (D), 1109 Pleasant St., Schenectady, N. Y.
Frandsen, John P. (B), 19—107th St., N. Troy, N. Y.
Goldstein, Bernard (D), 429 Division St., Schenectady, N. Y.
Harter, Grant E. (D), 411 Manning Blvd., Albany, N. Y.
Rainville, Philip A. (D), 94 Jackson Ave., Cohoes, N. Y.
Westbrook, Russell T. (B), 93 State St., Albany, N. Y.

NORTHWEST

Greer, R. H. (C), Associated Welding Labs., 722 Raymond Ave., St. Paul, Minn.

OMAHA

Cady, Clarence E. (B), Midwest School of Welding, Inc., 203 S. 10th St., 7th Fl., Omaha, Neb.
Norton, John H. (C), 4328 Seward St., Omaha, Neb.

PEORIA

Hyler, Loiell L. (C), R. G. Le Tourneau, Inc., Peoria, Ill.

PHILADELPHIA

Gayley, Charles T. (C), 271 Windemere Ave., Lansdowne, Pa.
Hoopes, James C. (D), 405 Marlin St., Folsom, Pa.

PUGET SOUND

Green, R. L. (D), 1162 Pitt Ave., Bremerton, Wash.
Nelson, J. T. (C), 2141 W. 96th St., Seattle, Wash.
Tobey, Grover A. (C), 4021 Chilberg Ave., Seattle, Wash.

QUAD CITIES

Jinks, Raymond S. (D), Sherrard, Ill.

ST. LOUIS

Hicks, Harold E. (C), Moloney Elec. Co., 5390 Bircher, St. Louis, Mo.

SAN FRANCISCO

Bihn, Leo J. (C), 941 Coleman Ave., San Jose, Calif.
Cohn, Sam, Jr. (B), Victor Equip. Co., 844 Folsom St., San Francisco, Calif.
Koll, Otto H. (B), Pacific Oxygen Co., 2205 Magnolia St., Oakland, Calif.
Labate, Vincent J. (D), 1129 Marin St., Vallejo, Calif.
Wood, Claude (D), 1440—56th Ave., Oakland, Calif.

SOUTH TEXAS

Parsons, James N., Jr. (C), 1907 Pearl St., Austin, Tex.

TULSA

Norton, Walter (C), 910 W. 3rd St., Tulsa, Okla.

WICHITA

Phillips, J. T. (B), 301 Old Manor Rd., Wichita, Kans.

NOT IN SECTIONS

Bardine, Calvert S. (C), P. O. Box 148, Keewatin, Minn.

Beserra, Cleopas (D), Garcia Amorales 48, Navajoa San, Mexico.

Bliss, Percy I. (C), Ascutney Blvd., Windsor, Vt.

Cartlidge, Willard A. (C), La Consolidada, S. A., P. O. Box 81-Bis, Mexico, D. F.

Cornwell, Rector (D), 123 N. Beech St., Casper, Wyo.

Darmos, Lawrence A. (D), 2227 Woodford St., Toledo, Ohio.

Lawson, James W. (D), Rt. 3, Box 1016, Klamath Falls, Ore.

MacLeod, Daniel (B), c/o Orr, 51 Bunessan St., Glasgow, S. W. 2, Scotland.

Morgan, James R. (C), 1810 Hunter Ave., Mobile, Ala.

Poyer, D. G. (D), 2007 La Fayette Ave., N., Grand Island, Neb.

Schickedanz, L. H. (B), United States Coal & Coke Co., Gary, W. Va.

Tucker, J. R. (A), Federal Aircraft & School of Welding, 1110–12 Union Ave., Memphis, Tenn.

SECTION ACTIVITIES

COLUMBUS

The July meeting of the Ohio State University Student Branch of the AMERICAN WELDING SOCIETY was held on July 8, 1942, at the Ohio Union on the campus with Clarence Shultheis, president, presiding.

The animated cartoon, "The Inside of Arc Welding" produced by the General Electric Company, was shown and enjoyed by all. The Executive, Social, Publicity, Membership and Library Committees were appointed by the president. William S. Wagner, a student member, was presented with the Arc Welding Scholarship by Charles E. MacQuigg, Dean of the College of Engineering. Clay Roberts, *Chairman* of the Columbus Section of the A.W.S., addressed the group briefly on the program of the Columbus Section for the coming year. J. L. Purdy, *Vice-Chairman* of the Columbus Section, was introduced. There were approximately fifty members and guests present.

DETROIT

The following appointments have been announced by the Detroit Section:

Publicity: W. F. Sherman. Reception: Henry Neitzel, *Chairman;* Mrs. Hakelow; Mr. Lewis; Mrs. Paul M. Corp; Mr. Last. Patrons List: William Hayes, *Chairman;* C. E. Phillips. Program: Ed. Biederman, *Chairman;* Louis Benkert; John Diebold; Don Corey; George Friebel; G. N. Sieger.

INDIANA

The following officers were elected for the year by the Indiana Section at their July 10th meeting:

Chairman, E. F. Gilyeat, J. D. Adams Co.; *Vice-Chairman*, R. J. Wirt, Delco-Remy Div., General Motor Corporation; *Secretary*, H. D. Weed, P. R. Mallory Co.; *Treasurer*, P. F. Grubbs, P. R. Mallory Co.

Executive Committee: E. F. Gilyeat, R. J. Wirt, H. D. Weed, P. F. Grubbs, R. H. Imes, W. H. McGlade, C. M. Sauer, P. B. Hall, C. W. Mercer, E. O. Smith. Publicity: C. M. Sauer, Air Reduction Sales Co., *Chairman*. Program: R. H. Imes, P. R. Mallory Co., *Chairman*. Membership: R. J. Wirt, Delco-Remy, *Chairman*. Prestige: W. H. McGlade, J. D. Adams Co. War Ind. Adv. Comm.: W. H. McGlade, *Chairman*.

MARYLAND

A special meeting will be held on September 18th to view a film on welding. The Maryland Section is working on a program for an educational series of lectures on welding to be held twice monthly from September through January.

NORTHERN NEW JERSEY

Mr. W. H. Hart of the Charles W. Krieg Co., Newark, N. J., has been elected *Secretary-Treasurer* of the Northern New Jersey Section to fill the unexpired term of Mr. H. S. Card.

NORTHERN NEW YORK

A special showing for members and their guests of all six parts of "The Inside of Arc Welding" was made on August 6th at Union College. Following the presentation of the film, a lively discussion took place.

The Meetings and Papers Committee of the Northern New York Section have a program outlined for the winter that proposes to start with a smoker in October and follow with five good technical sessions, skipping December and finishing in April.

PITTSBURGH

The following officers have been elected by the Pittsburgh Section for the 1942–43 season:

Chairman, F. H. Dill, American Bridge Co.; *Vice-Chairman*, H. P. Schane, Allis-Chalmers Mfg. Co.; *Secretary*, J. F. Minnotte Brothers Co.

Executive Committee: R. J. Lee, Roy W. Emerson, W. F. A. Fitzgerald, G. O. Hoglund, W. H. Kauffman, Williams & Co.; C. P. Streithof, Dravo Corporation.

A meeting of the new officers and members of the Executive Committee met in the William Penn Hotel August 7th and discussed plans and procedures for the coming season.

It was voted to continue meetings in the Mellon Institute of Industrial Research Building; plans were discussed for the type of meetings to be held and the setup of various committees to function was left to the appointment by the *Chairman*. The first meeting is planned for October 21st.

PUGET SOUND

The following officers were elected at the last regular meeting of the season on July 15th by the Puget Sound Section:

Chairman, Sydney K. Smith, American Bureau of Shipping; *Vice-Chairman*, Carl H. Buchenroth, Seattle, Wash.; *Secretary-Treasurer*, J. T. Nelson, Seattle, Wash.

SAN FRANCISCO

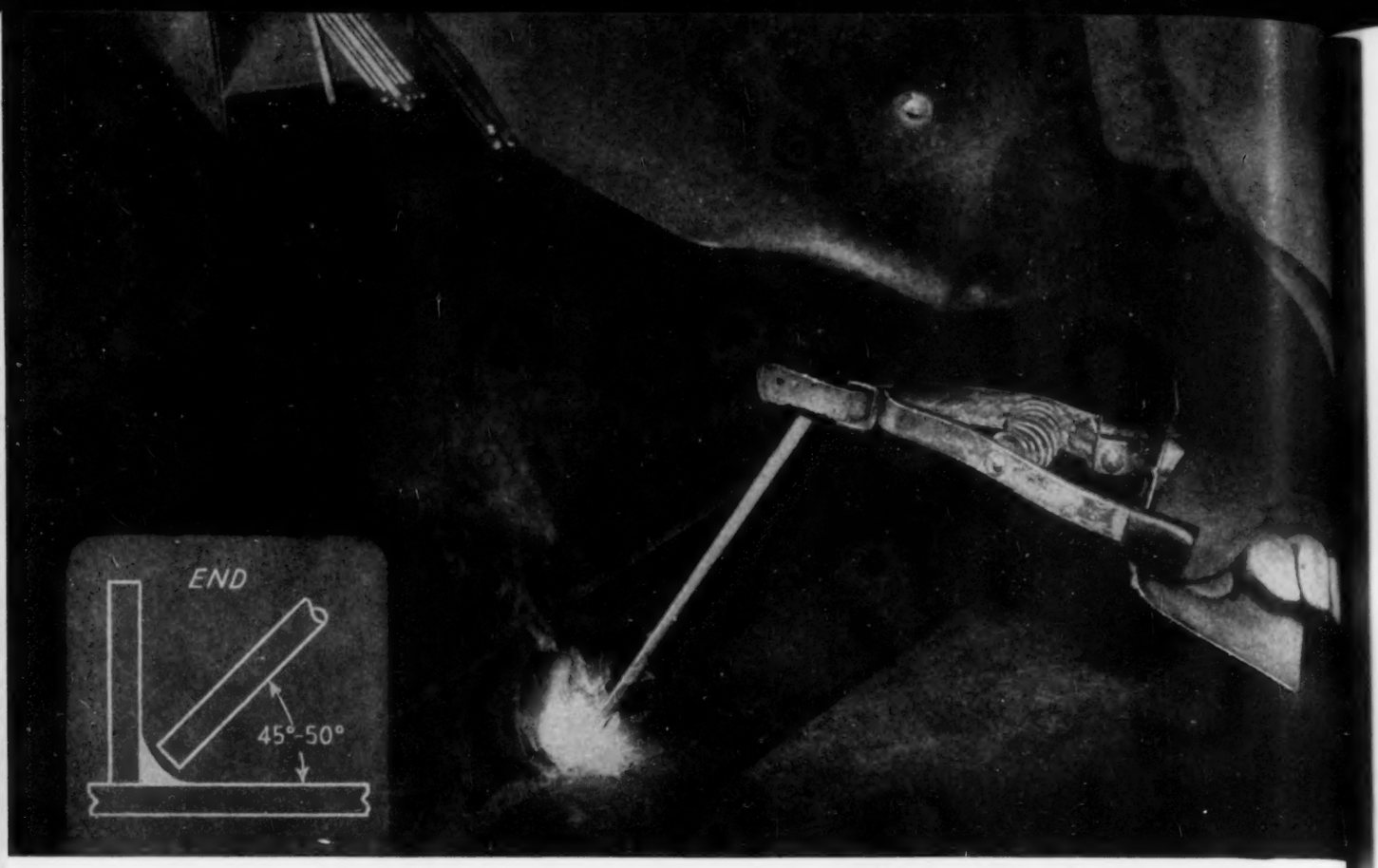
A large attendance of about 250 members and guests attended the July meeting of the San Francisco Section held on the 31st. A forum discussion of welding in the shipbuilding industry, evolved into a heated discussion between Harry Brink of the Western Pipe and Steel Company, who championed the cause of all other construction of ocean-going vessels; James Kroner, Richmond Shipyard No. 1, who championed the cause of riveted frames and welded shell construction; and W. L. Rickett of the Bethlehem Steel Company, who championed the cause of the combination welded and riveted construction. This lively discussion developed many points of interest.

Six reels of the film "The Inside of Welding" were very well received.

ST. LOUIS

The annual installation of officers for the St. Louis Section was held on June 5th at the York Hotel. The following are the officers elected.

Chairman, A. S. Schwarz, John Nooter Boiler Works Co.; *Vice-Chairman*, E. F. Meier, Monsanto Chemical Co.; *Secretary*, H. C. Close, Machinery and Welder Corp.; *Treasurer*, M. J. Letich, Combustion Engrg. Co.; *Directors*, W. S. Evans, A. W. Harris, Lockwood Hill, Norman Moss, I. T. Olson, H. H. Sheaff.



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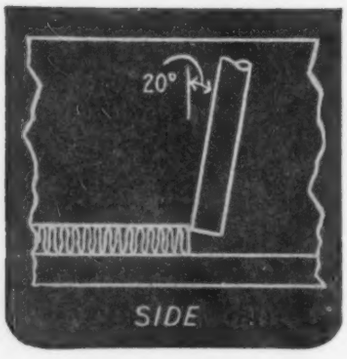

ASSUMES NEW IMPORTANCE IN THE DRIVE TO CONSERVE ELECTRODES

THIS photograph shows a method taught by Murex Engineers for more than ten years and used by many experienced welders to speed fillet welding. It also saves up to 40% of the weld metal, produces a substantially stronger weld and at the same time helps to conserve precious welding electrodes.

First: The electrode is held at an angle of from 45° to 50° to the horizontal plate and leaning in the direction of welding to form an angle of about 20° with the vertical.

Second: In multiple pass work, beads are laid from the bottom upward—not from the top downward.

Third: Cleaning time can be saved and the work speeded by leaving on the slag until each layer of beads is completed.

Fourth: Select a rod which permits the use of high current and use the largest size electrode that is practical.

METAL & THERMIT CORPORATION
120 BROADWAY, NEW YORK, N. Y.

Specialists in welding for nearly 40 years. Manufacturers of Murex Electrodes for arc welding and of Thermit for repair and fabrication of heavy parts.

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MUREX
ARC WELDING ELECTRODES

TENTATIVE PROGRAM

TWENTY-THIRD ANNUAL MEETING
AMERICAN WELDING SOCIETY
WEEK OF OCTOBER 12, 1942

HOTEL CLEVELAND, CLEVELAND, OHIO

Make Room Reservations Early—Direct with Hotel Cleveland

Arrive Sunday 11th—(Convention Hotel) Rates Apply for Short or Long Stay

National Metal Exposition, Public Auditorium—Open Afternoons and Evenings Throughout the Entire Week, Commencing October 12, 1942

IMPORTANT

ALL Technical Sessions will positively start on time.

No Stenotype Reporter—Members desiring to discuss papers are urgently requested to prepare discussion in writing in advance of the meeting and to send copies to headquarters as those preparing written discussion will be given preference at the sessions. Members and guests giving extemporaneous discussion at meeting should forward a written transcript of discussion as soon as possible after the meeting.

Members and guests are urged to REGISTER immediately upon arrival at A. W. S. HEADQUARTERS and obtain Convention Badge admitting them to Exposition.

NO REGISTRATION FEE but a charge of $1.00 (per member) and $1.50 (non-member) is made for Technical Sessions Papers.

Registration hours throughout the week:

Hotel Cleveland
Monday, Tuesday and Wednesday 9 A.M. to 5 P.M.
Thursday 9 A.M. to 12 Noon

Public Auditorium
Monday, Tuesday and Wednesday 12 Noon to 10 P.M.
Thursday 12 Noon to 6 P.M.

MONDAY, OCTOBER 12th, Morning—9:30 A.M.

OPENING SESSION

Ball Room

Chairman—G. F. JENKS,
President, American Welding Society

Vice-Chairman—E. V. DAVID,
Chairman, Convention Committee

PRESENTATION OF MEDALS AND PRIZES

TECHNICAL SESSION—10:15 A.M.

TRAINING OF WELDING OPERATORS AND QUALIFICATIONS

Ball Room

Chairman—K. L. HANSEN,
Harnischfeger Corp.

Vice-Chairman—E. T. SCOTT,
Cleveland School of Welding

Training of Welding Foremen, by F. H. ACHARD, Supervisor of Training, Consolidated Edison Co. of New York, Inc.
Instruction Methods in Welding Developed by U. S. Office of Education, by H. K. HOGAN, U. S. Office of Education

OPENING METALS EXPOSITION—12:00 Noon

NOTE: All Technical Sessions are on Mezzanine Floor

Monday Afternoon—2:00 P.M.

SIMULTANEOUS TECHNICAL SESSIONS

Red Room
FATIGUE AND IMPACT

Chairman—A. E. GIBSON,
Wellman Engineering Co.

Vice-Chairman—F. L. PLUMMER,
Hammond Iron Works

Fatigue Strength of Metal Subjected to Combined Stresses
by L. H. DONNELL, Illinois Institute of Technology

Fatigue Strength of Commercial Butt Welds in Carbon Steel Plates
by W. M. WILSON, University of Illinois

Fatigue Tests of Full Thickness Plates with and Without Butt Welds
by E. C. HUGE, The Babcock and Wilcox Co.

Impact Strength of High Alloy Steel Welds
by E. C. CHAPMAN, Combustion Eng. Co.

Ball Room
WAR PRODUCTION

Chairman—R. J. KRIZ,
The James H. Herron Co.

Vice-Chairman—A. F. DAVIS,
The Lincoln Electric Co.

Some Special Applications of Flame Hardening
by STEPHEN SMITH, Air Reduction Sales Co.

High Quality Welding—Vertical and Overhead Positions with Alternating Current
by H. O. WESTENDARP, General Electric Co.

Conservation and Effective Use of Equipment and Supplies for Welding and Cutting
by H. ULLMER, The Linde Air Products Co.

Welding Gun Mounts
by W. B. LAIR, York Safe and Lock Co.

Monday Evening—7:30 P.M.

MOTION PICTURE FILMS

Red Room

The Inside of Welding—Educational film by General Electric Company

The Welding of Aluminum—Aluminum Company of America

The Welding Technique—Oklahoma A. & M. College

Industrial Research Dinner — Rose Room

TUESDAY, OCTOBER 13th, Morning—9:30 A.M.

SIMULTANEOUS TECHNICAL SESSIONS

Ball Room
WELDABILITY OF STEEL

Chairman—A. B. KINZEL,
Union Carbide and Carbon Res. Labs.

Vice-Chairman—A. E. MARBLE,
Firestone Tire & Rubber Co.

What Happens To Residual Stresses in Service
by J. T. NORTON and D. ROSENTHAL, Massachusetts Institute of Technology

Effects of Cooling Rate on the Properties of Arc Welded Joints
by W. F. HESS, Rensselaer Polytechnic Institute

Weld Quench Gradient Tests
by W. H. BRUCKNER, University of Illinois

Red Room
AIRCRAFT WELDING (Fuselage)

Chairman—P. H. MERRIMAN,
The Glenn L. Martin Co.

Vice-Chairman—J. F. MAINE,
Republic Structural Iron Works

Welding of Airplane Propeller Blades
by C. A. LIEDHOLM, Curtiss-Wright Corp.

Welding of New Types of Alloy Steels for Aircraft Structures
by A. R. LYTLE and K. H. KOOPMAN, Union Carbide and Carbon Res. Labs.

Effect of Current on the Welding of X4130 Sheet and Tubing
by W. T. TIFFIN, University of Oklahoma

Tuesday Afternoon—2:00 P.M.

SIMULTANEOUS TECHNICAL SESSIONS

Ball Room
WELDABILITY OF STEEL

Chairman—C. H. JENNINGS,
Westinghouse Elec. and Mfg. Co.

Vice-Chairman—G. B. CARSON,
Case School of Applied Science

Weldability of Carbon-Manganese Steels
by O. E. HARDER and C. B. VOLDRICH,
Battelle Memorial Institute

Assembly B
AIRCRAFT WELDING (Sheet)

Chairman—G. O. HOGLUND,
Aluminum Company of America

Vice-Chairman—JOHN D. GORDON,
Taylor-Winfield Corp.

Spot Welding in Aircraft Structures
by E. S. JENKINS, Curtiss-Wright Corp.

Red Room
GAS CUTTING

Chairman—J. R. DAWSON,
Union Carbide and Carbon Res. Labs.

Vice-Chairman—O. L. SMITH,
Weldit Acetylene Co.

Tuesday Afternoon—2:00 P.M. (*Continued*)

SIMULTANEOUS TECHNICAL SESSIONS

WELDABILITY OF STEEL

Weldability Tests of Carbon-Manganese Steels
by C. E. JACKSON, M. A. PUGACZ and G. G. LUTHER, Naval Research Lab.

Jominy End Quench Hardenability Tests on Carbon-Manganese Steels
by G. A. TIMMONS, Climax Molybdenum Company

Tee-Bend Tests on Carbon-Manganese Steels
by L. C. BIBBER and J. HEUSCHKEL, Carnegie-Illinois Steel Corp.

AIRCRAFT WELDING (Sheet)

Standards and Recommended Practices and Procedures for Spot Welding Aluminum Alloys
by G. S. MIKHALAPOV, Chairman, Aircraft Welding Standards Committee

Arc Welding of Magnesium Alloys
by W. S. LOOSE and A. R. ORBAN, The Dow Chemical Co.

Welding — Its Application to Aircraft
by FRANCIS H. STEVENSON, Vega Aircraft Corp.

GAS CUTTING

Gas Cutting in Steel Mills
by S. D. BAUMER, Air Reduction Sales Co.

Improved Methods of Machine Flame Cutting
by H. E. ROCKEFELLER, The Linde Air Products Co.

Gas Cutting in Shipbuilding
by R. F. HELMKAMP, Air Reduction Sales Co.

Evening—7:30 P.M.

Red Room

Fundamental Research Conference—H. C. BOARDMAN, Chairman, Presiding

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WEDNESDAY, OCTOBER 14th, Morning—9:30 A.M.

SIMULTANEOUS TECHNICAL SESSIONS

Assembly B

RESISTANCE WELDING

Chairman—G. N. SIEGER, S-M-S Corporation

Vice-Chairman—B. L. WISE, Federal Machine & Welder Co.

Refrigerant Cooled Spot Welding Electrodes
by F. R. HENSEL, E. I. LARSEN and E. F. HOLT, P. R. Mallory & Co.

Spot Welding of 0.040 In. Thickness SAE X4130 Steel
by W. F. HESS and D. C. HERRSCHAFT, Rensselaer Polytechnic Institute

Unusual Resistance Welding Developments and Operations
by R. T. GILLETTE, General Electric Co.

Resistance Welding Trench Mortar Fin Assembly
by J. H. COOPER, Taylor-Winfield Corp.

Red Room

PRODUCTION WELDING

Chairman—O. B. J. FRASER, International Nickel Co.

Vice-Chairman—D. H. COREY, The Detroit Edison Co.

Welding with Aluminum Bronze
by CLINTON E. SWIFT, Ampco Metal, Inc.

Adapting Automatic Electric Welding to Routine Production
by J. M. KEIR, The Linde Air Products Co.

Welded Steel Tube and Its Application in War Production
by H. S. CARD, Formed Steel Tube Institute

Wednesday Afternoon—2:00 P.M.

SIMULTANEOUS TECHNICAL SESSIONS

Assembly B

RESISTANCE WELDING

Chairman—R. E. POWELL, Western Electric Co.

Vice-Chairman—J. D. TEBBEN, P. R. Mallory & Co.

The Spot Welding of NAX High Tensile Steel
by C. R. SCHRODER, Great Lakes Steel Corp.

Application of Copper Oxides Rectifiers for Resistance Welding
by R. L. BRIGGS, Thomson Gibb Electric Welding Co.

The Effect of Weld Spacing on the Strength of Spot-Welded Joints
by R. DELLA-VEDOWA and M. M. ROCKWELL, Lockheed Aircraft Corp.

Ball Room

WELDING AND CUTTING OF ORDNANCE

Chairman—H. L. R. WHITNEY, War Production Board

Vice-Chairman—H. C. BOARDMAN, Chicago Bridge & Iron Co.

Factors Affecting the Accuracy of Ordnance Machine Cutting
by HOWARD HUGHEY and A. H. YOCH, Air Reduction Sales Co.

Manual and Automatic Welding of Heavy Plate of Hardenable Alloys
by L. A. DANSE, Cadillac Motor Car Div.

Developments in Cast Iron Welding Rods and Electrodes
by R. J. FRANKLIN, Chicago Hardware Foundry Co.

Red Room

SHIPBUILDING

Chairman—DAVID ARNOTT, American Bureau of Shipping

Vice-Chairman—A. L. PFEIL, Universal Power Corp.

Suggested Methods Which Will Increase Welding Production and Decrease Welding Costs
by J. F. LINCOLN, Lincoln Electric Co.

Distortion and Shrinkage Problems in Ships and Other Large Structures
by LAMOTTE GROVER, Air Reduction Co.

Motor Boat Construction and Small Ships
by W. E. WHITEHOUSE, Defoe Shipbuilding Co.

Wednesday Afternoon—2:00 P.M. *(Continued)*

SIMULTANEOUS TECHNICAL SESSIONS

RESISTANCE WELDING

Preparation of Aluminum Alloy for Spot Welding
by T. E. PIPER, Northrop Aircraft, Inc.

WELDING OF ORDNANCE

Electric Welding of Mobile Artillery Gun Carriages
by G. E. CAMPBELL, Pettibone-Mulliken Corp.

SHIPBUILDING

Application of Welding in Submarine Construction
by E. H. EWERTZ, Electric Boat Co. and R. D. WEST, Manitowoc Shipbuilding Co.

Evening—7:30 P.M.

Rose Room

Section Officers Dinner and Conference

THURSDAY, OCTOBER 15th, Morning—9:30 A.M.

SIMULTANEOUS TECHNICAL SESSIONS

Red Room

AIRCRAFT WELDING

Chairman—S. L. HOYT,
Battelle Memorial Institute

Vice-Chairman—E. VOM STEEG,
General Electric Co.

Utility Characteristics of Aircraft Electrodes
by C. B. VOLDRICH and R. D. WILLIAMS, Battelle Memorial Institute

Results of Survey on Current Arc Welding Practice in Aircraft Industry
by MAURICE NELLES, Chairman, Western Aircraft Welding Committee

Copper Welding for Aircraft
by T. V. BUCKWALTER, Timken Roller Bearing Co.

Assembly B

NON-DESTRUCTIVE TESTS AND INSPECTION

Chairman—J. J. CROWE,
Air Reduction Sales Co.

Vice-Chairman—O. R. CARPENTER,
Babcock & Wilcox Co.

Correlation of Metallographic and Radiographic Examinations of Spot Welds in Aluminum Alloys
by DANA W. SMITH and FRED KELLER, Aluminum Company of America

The Magnetic Powder Method for Inspecting Weldments and Castings for Sub-Surface Defects
by CARLETON HASTINGS, Watertown Arsenal

Radiographic Inspection of Welded Armor Plates and Castings
by DON M. MCCUTCHEON, Ford Motor Company

Visual Inspection of Arc Welds
by W. L. WARNER, Watertown Arsenal

Thursday Afternoon—2:00 P.M.

Business Meeting

Rose Room

3:00 P.M.

Board of Directors Meeting

Room 1

Convention Headquarters—Mezzanine Floor
Registration—Mezzanine
Office—Director's Room
Press—East Room
Ladies Reception—Powder Room
Lounge for Members—Assembly A
6 Committee Rooms—Rooms 1, 3, 5, 7 & 9, and Rose Room